MICHAEL D. GODFREY

SKIING AND SCIENCE

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1

Introduction

"Those who are good at archery learned from the bow, and not from I^d the Archer. Those who can think learned from themselves, and not from the sages."

From the *Kuan Yin Tzü*

"The attainment of knowledge lies in the investigation of things."
From the *Ta Hsüeb*

Quotes above from: *Science in Traditional China*
A Comparative Perspective
by Joseph Needham
Cambridge Press, 1981, pg. 119 (36)

In Summary

It is evident that the earth's habitable land mass will decrease due to global warming while the total population may, for some time, continue to increase. However the most likely long term is population loss.[1] While the future of climate change is not certain it is likely that global warning will prevail. For more detailed study see current issues of the journal Climate change This cannot, due to increasingly scarce resources, continue in a manner that is likely to seem fair to everyone. It will more likely end in chaotic destruction.[2]

[1] Is this a threat or a promise?

[2] As Alan Bennett said: The least understood time is the recent past.

1.1 Acknowledgments

I am very pleased to mention the help and encouragement from David B. Zierler, Caltech Heritage Project Director and Senior Strategist <dzierler@caltech.edu>. Without his help much would have been less clear or well-stated.

And, of course I have benefited in more ways than I can express from the teachers at Deerfield Academy, Caltech, and the London School of Economics. Then, of course, on arrival at Princeton it was Oskar Morgenstern and John Tukey who provided much knowledge and encouragement. I worked with John Tukey on a continuing basis at both Princeton and the Bell Labs at Murray Hill. Oskar Morgenstern provided support, a font of knowledge, and very many helpful contacts throughout the US and Europe.

1.2 Brief Review of Scientific Research in our Time

There is no doubt that Scientific Research reached unprecedented achievements[3] during the period following World War 2.

[3] However, watch out for results that are "more true in general than in any specific case"!

It is disappointing that after the 1992 divestiture of AT&T independent scientific research has been very substantially reduced. Specifically, nearly all of the industry research labs, most prominently the Bell Labs facilities, were forced to close. This came about due to the 1982 Consent Decree issued by the US Justice Department which was addressed to AT&T. This decree required the breakup of AT&T into separate corporate entities. Initially some of the labs continued as a part of the separate companies. But, they all finally scaled down or closed.

When established AT&T was the only corporate enterprise that had the resources and vision to carry out fundamental research on an effective scale.

Due to the AT&T lab closures, the GE Labs, and most other industrial labs have also been closed.

This came about due to IBM's intense and successful effort to destroy AT&T. They saw AT&T as a potential competitor who could restrict their entry into communication businesses. As evidence of this intent IBM had secretly bought one of the independent telephone companies in preparation for their plan. AT&T senior management was not aware of these actions until too late.

1.3 Loss of Access to Information

An additional severe loss has been the sequence of extensions of the copyright law. This was principally demanded by and provided for the entertainment industry. However it has been equally applied to copyright of publications, most importantly including all scientific works. The result is that scientific publications are held under what is in effect indefinite copyright restriction. The current US restrictions are described at: US Copyright Law. Publishers and authors can, of course, make their own choices. Despite all this, and the current drastic reductions in the US, other nationally funded research continues and produces new knowledge.

1.3.1 Exceptions

Importantly, Caltech provides a liberal interpretation of copyright for its staff which is expressed in its policy statement at: Caltech Open Access Policy.

And, Cambridge Press provides a liberal copyright for Academic works. The authors of publications for courses are allowed to distribute any course related publications in PDF form for all the students. Cambridge Press has found that quite a few print copy versions are also purchased.

1.4 Jet Propulsion Lab

As an offset to the somewhat discouraging picture that I have just described it seems appropriate to mention one of most important ongoing research efforts.

As a nearly unique enterprise the Jet Propulsion Lab (JPL) at Caltech has produced substantial new knowledge of the universe and its objects. See: https://www.jpl.nasa.gov/ for a full and fun review of their contributions. This is made widely available under the Caltech access policy mentioned above.

And also, the internationally funded WEBB telescope is a dramatic extension of what can be seen far out in the universe. This was an amazing achievement. The telescope assembly was only completed for correct imaging after the launch of the delivery vehicle into its orbit.

See: NASA: About the WEBB telescope. Or, the WEBB Space Telescope Image Gallery.

2
A Beginning

I was born in Portland Oregon on 30 May 1937. But I first lived in Eugene Oregon with my mother and father. Then, after Perl Harbor my father joined the Army officers' training program and I did not see him again until after the War. With my mother, we traveled often in the Western States as indicated in the chronology below at Section 3.1, And, for those who prefer to skip ahead the conclusion is at Chapter 35 where we settled in London.

My interests have always been to understand how things work and how they can be made to work "correctly."[1].

In short, when asked what I do, the answer has always been: "I just work here." The reactions to this have been interesting.

I have three heroes from whom I learned *The Minimum Work Principle* and much else:

Émile Allais explained the principle in his book, *La Méthode Française de Ski* by Émile Allais (1) as: "ski in harmony with the mountain." Allais' book is also available at: [https://archive.org/details/Allais-methode-francaise-de-ski/mode/1up].

Richard Feynman explained the same principle in *The Feynman lectures* Volume II, Chapter 19 "The Principle of Least Action" (Feynman Lectures). These are instances of the same minimum work principle, just expressed in differing domains. No other principle appears to be simpler nor more compelling.

I have also applied this principle in the form that if I happen on what seems a useful challenge I always try to find someone to take it on. Only if all else fails do I try to do it myself.

Michael Faraday played a key role due to his fundamental insights and his dedication to science without distracting influences. His values have, I hope, guided my professional life in as useful a manner as I could manage.

Faraday, Ampère and Maxwell were the group, working together, that

[1] My choices are easy to describe: I follow the *minimum work principle:* if work is needed I try to find someone else to do it. Or, only if necessary I undertake to do it!

developed electromagnetism. See Section 22.2 for a full discussion of this work.
J. H. Gladstone (21) is the only author that I have found who provides a full and accurate description of of this work and including Faraday's life and contributions.
The best source for Gladstone is: Michael Faraday, Cambridge Press
Sadly, other attempts to provide an accurate biography fail in a fundamental way. They all portray Faraday as "primitive" and only give credit to the full development of electromagnetism to Maxwell and possibly Ampère. This is not accurate.
Expansions on these remarks will appear in subsequent Chapters. A chronology is provided in Section 3.1 below.

2.1 *Babbage and The New Science*

Babbage(3) invented important scientific instruments in the mid 1800's these only became widely available in the mid 21st century.
This introduced a fundamental change in scientific investigation which took place in the mid 21st century. This change replaced long standing early study and recording by means of essentially hand measurement. This typically made use of a ruler or equivalent. The measured value was then written out based on some scale. This was subject to variable errors.
Finally, this has been replaced by recording in *digital* form using a suitable instrument. These are not quite exact definitions, but examples are strip chart recorders producing a trace on paper whereas digital examples are a sensed property being recorded by an instrument which displays or records a number of digits. The number of digits are usually chosen based on the capabilities of the recording devices and the accuracy required for capturing the information that was to be recorded. This represents a fundamentally better basis for recording and analysis.
It was Babbage(3) who led this transition. He was also one of the key error correctors of the marine navigation tables. These tables permitted ships to be guided by the positions of the stars. However, an error in the charts could and did result in shipwreck. He also corrected insurance annuity tables.

2.2 *An aside*

This just comes to mind: the court Jester inadvertently offended the King who announced "off with his head". But, the Jester responded: Please your Majesty if you delay my execution for one year I will teach your favorite horse to talk. The King thinks and then agrees. But, the

Jester's friend says: You cannot teach the horse to talk! The Jester replies: of course not, but in a year's time the King may die, the horse may die, I may die, or the horse may learn to talk.

3

Early Childhood

My early childhood experiences seemed quite typical as I had little opportunity for comparison. Others may have had similar experiences. Here are a few of mine.

When I first attended a school I noticed that all the other children had parents named Mom or Dad. I asked how can this be? My parents names, which we always used, were George and Augusta. This was, I am quite sure, my mother's decision.

In any case she always treated me as an adult. However, she also wished that I had been a girl and I was dressed accordingly for several years.

She also considered formal schooling as quite optional, so for the early years I only attended school for a week or two from time to time. Very little was learned in the temporary schools except for one to be described below.

Subsequently, at age 15 I decided to undertake an education focused on science, and continue my life's work in research, education, and applications of scientific methods in useful ways. It was my hope that this would prove helpful.

3.1 *Chronology*

Here is a chronological summary:

Brief Chronology

Date	Location	activities
1937	Eugene, Oregon	Just starting growing up
1939	Neskowin	Summers at the Oregon Coast
1940	Travels in Western USA	Some occasional schooling
1947	Montreux and visits to Bavaria & Munich	School in French and effects of War Skiing learned from Émile Allais
1949	Munich	Learning about the war and full-time skiing
1952	Deerfield Academy	Study and still skiing, most happily at Mad River Glen
1955	California Institute of Technology	No skiing, serious learning
1959	London School of Economics	M. Peston, Game Theory, Statistics, Economics, and latest computing systems and languages
1962	Princeton University, Morgenstern and Tukey	Introduced me to new ideas and opportunities
1967	Bell labs, Murray Hill	Initial study of AT&T system technology and planning
1969	Imperial College, London,	Math Dept. Reader in Statistics and AT&T Corporate headquarters New York Research and analysis of AT&T MTS Services
1977	Sperry Univac, Blue Bell, PA	Head of Research: Introduced new CMOS technology, paged memory and reliable and secure systems
1983	ICL, Head of Research, London.	Report on business viability. Company sold to Fujitzu
1986	Imperial College, Schlumberger Professor	Signal processing and wavelet transforms
1989	Stanford, Visiting/Consulting Professor, ISL Lab	Signal processing and analog circuits for imaging
2010	London	Time to think and reflect on our Golden Age
2022	London/Bay Area	Time spent in the Bay Area where we found that the Golden Age will not return. Sad goodbye.
2023	London	And so to return, finally, to London. Discovered Babbage's completion and verification of his Analytical Engine. (using his invented RTL). For details see his autobiography (3). Ilse was accepted at The Chelsea Arts Club. A happy and exciting Place.

3.2 *Travel in Oregon and Western States*

This period started when I was about five. Augusta was independent minded and expected me to be the same. Occasionally, she gave advice: we were driving through Bismark, North Dakota, and I noticed a very odd building which proved to be a Gothic church (It is a replica of the Votivkircke in Vienna.). Not knowing what that was I asked Augusta and was told: "That is a church: you do not want to know anything about that kind of thing."

During this period I only occasionally attended school. This happened when we stayed in one place for more than a week or two.

There were two memorable school related events in this period. First was a school where it came time to learn some "math." The assignment was to memorize the multiplication table. I stated that I could not do this. The teacher was outraged and declared that I was the dumbest student she had ever had and that I would surely fail in later life. To this day memorizing the multiplication table is still often taught as "mathematics." This is particularly unfortunate as this is not what is required for understanding the mathematics used in computers which is in many cases based on linear algebra. Linear algebra is still not widely taught until at University courses. There is an effort to change this, but progress is slow since few teachers know linear algebra. So, first the teachers need teaching.

3.3 *A New Educational Event*

The second interesting educational event was quite the opposite of the previous one. We were staying on a large ranch in Arizona which provided a single room school for all the children. There were about 15 children ranging in age from about first grade to age about 12. The teacher did not live at the ranch but had to drive out from Tucson. She showed up some days, but not others.

So, I asked one of the students what to do. He said: look for books with the "right" number on them, i.e. ones that seem to match to your age. After reading those books, try one with a higher number. During the roughly three months that we lived on the ranch I read through about 4 consecutive book numbers. It was about 8 years later before I again learned at a comparable rate. I also learned to ride horses and participate in the work of the ranch.

As previously indicated, my mother was quite exceptional in her approach to raising children. At the time it seemed to me to be natural and interesting. But I also began to try to figure out how things worked, such as sewing machines, record players, and radios.

4

Tolerance and WW2

A value that my mother taught me was, to quote her exactly: **The only thing that I cannot tolerate is intolerance.** I have attempted to follow this in good times and bad. Failure to do so leads to more harm than good.

4.1 Initiation of World War II

World War II interrupted this broadly peaceful and tolerant period.

At the end of 1941 due to the Pearl Harbor attack my father joined the US Army Officer Training Corps. Therefore, I did not see him again until after the war. This meant that during this period I was entirely raised by my mother.

She had definite views about raising children.[3] First, nearly from birth I was treated as an adult. This included that if I wanted to go outside to play, that was fine and I was only told to come back when I felt like it. I also learned Shakespeare, the romantic poets, mainly Wordsworth and Coleridge. And learned to knit and sew. At least initially, my mother definitely wished that I had been born a girl.

[3] Learning to be an independent person.

I found my own way. I particularly liked operating the pedal-driven sewing machine and playing records on a windup gramophone and, of course, listening to Wild West dramas on the radio. I was very much interested in how such devices worked. How did a sound come out of a gramophone record and how did a radio similarly produce sound apparently out of thin air? As I learned how such things worked this knowledge was put to practical use.

4.2 *The War Years and Immediate Aftermath*

There was a widely held sense of accomplishment and a sense that science and engineering along with efficient planning of resources could contribute in an essential way to winning the war and could help in the recovery and beyond. Of course it was essential to obtain the information necessary to make effective decisions.

There were dissenters such as Charlie Wilson the then Wartime Secretary of Defense and formerly President of General Motors. And, wealth and opportunity were not always equally shared. But even for the traditionally poor and underprivileged by race, color or misfortune there was a perception of possibilities that had not previously existed.

It was an amazing privilege to come of age in this period. Young people enjoyed many opportunities and for most of them debt was unheard of or at least manageable. Still, near the end of this period there were signs: Rachel Carson's 1962 publication *The Silent Spring* (13) provided a warning and, of course, there were racial and sex biases. But there was a sense that these were being substantially, if slowly, addressed. And there was hope.

5

Digression

Every person is unique and every person's experiences are also unique. In addition, everyone is likely to respond to events differently in many fundamentally different ways. There is much more to this point than is often recognized.

It is commonly assumed that most people are quite similar even though their surroundings and experiences may differ. This applies to both physical and mental characteristics. However, evidence shows that there are wide and pervasive differences between individuals. Some individuals can multiply very large numbers in their heads. Some, it is claimed, particularly Chinese students, can do this by "pretending" that they have an abacus. Just moving their fingers as they would to operate the abacus produces the correct answer! Others can solve complex mathematical problems entirely in their heads, and others can memorize a book and then, when asked, recite exactly any selected page. (I know this as I had a classmate at Deerfield Academy who could do it! However, he did not do so well when reasoning was required.)

Related to this is the popular "trick" question: Two trains start out approaching each other when 120 miles apart and traveling at 60 mph. A bird starts from one train flying to the other, then returning and so on until the trains meet. The question is: how far had the bird flown when the trains meet?[1] Many people find this question difficult since the bird makes a series of flights from one train to the other, each flight shorter than the one before it. It is claimed that when John von Neumann was asked this question he immediately answered 60 miles! The questioner was surprised and said: "Ah, you noticed the trick." von Neumann answered "What trick? I just evaluated the length of each flight segment and summed all the segments." A trick, of course, is to notice that the time it took for the trains to meet was 1 hour. Therefore, the bird was

[1] How far has the bird flown?

flying at 60 mph for 1 hour. And it flew a total of 60 miles. No need to evaluate the length of each term and and compute the sum. But for von Neumann it appeared that summing the series was easier. However this story is told in various versions. There seems to be no confirmation about what von Neumann actually said.

In any case, von Neumann could solve complex sets of differential equations in his head in a matter of seconds. The story is told that a group in the Physics Department had just listened to a graduate student presenting his current work. He explained that after long efforts and using the available computer system he had gotten the result that he presented on the blackboard. After the student left von Neumann came in. He looked at the problem statement and immediately said: Good! He got quite close to the correct answer.

5.1 Misleading Information

Doctors learn that each patient responds to medications in a different way. They are trained to try one prescription, if that does not work, try another, and another. Aspirin appears to be the only widely useful medication.

And no human characteristic comes close to following the Normal (or also termed Gaussian) probability distribution. The Normal has the property that most values are clustered symmetrically about the mean with values farther from the mean falling off to form the usual bell-shaped curve, but the values never reach zero. There are conditions under which this distribution is appropriate. And, it is frequently assumed in practice since it allows simple tests and apparently significant conclusions. However, this is not appropriate for humans.

5.2 Wrong Conclusions – Ioannidis

This problem is explained in: Ioannidis, "Why Most Published Research Findings Are False" PLOS Medicine, August 30, 2005. And see also the correction at: PLOS Medicine, August 25, 2022. It is worse than useless when false positive results are published. Even after the original result is shown to be NOT significant the original result is often still referred to as stated in the original publication.

If wrong conclusions are drawn from the false claims substantial harm may be caused, particularly in medical contexts. Prescribing medical treatments which are useless, or worse, is harmful, but avoidable

if appropriate statistical testing were to be done on a more rigorous foundation before results are published or treatments prescribed.

For populations which are subject to evolutionary rules, wide diversity tends to enhance survival against major environmental changes. Thus, the variation is likely to be much wider than the Normal would indicate. However, it is doubtful if even this may work today when fundamental environmental changes due to human activities are occurring at a rapid rate.

6

A Golden Age

The immediate post WW2 period which extended into the 1970's was a Golden Age. This was most prominent in the US.

It was also extended into Europe, initially in large part due to the Marshall Plan

However, the Marshall Plan for Europe was only approved by Congress and signed by Truman on April 3, 1948, after a delay of about 3 years. The delay was due to substantial opposition in Congress. The opposing view was that Germany, under the proposed Morgenthau Plan, would be permanently reduced to an exclusively agricultural society. See on Wikipedia: Morgenthau Plan

The Golden Age also developed in parts of Africa and Asia in part due to the developments in the US and Europe.[1]

[1] The all too brief Golden Age of fairness, opportunity, family unity, care, and joy. Followed by poverty of income, education, opportunity, and loss of a fair role in a no longer fair society.
The rich get richer.

6.1 Key Background Events

The Golden Age in the United States had its foundation due to enactment of the Glass-Steagall Act in 1933. This act was a Roosevelt initiative following the banking crisis of 1929. A key provision of the Act was that investment and commercial banking activities had to be separated. Commercial banks mainly provided personal or small business loans and mortgages and were not allowed to carry on interstate business. Thus they were institutions which operated within the local communities where they were established. Quite often, the banker who approved your home loan was a neighbor.

However, the Gramm-Leach-Bliley Act of 1999 eliminated the Glass-Steagall Act's restrictions against affiliations between commercial and

investment banks. (See: Gramm-Leach-Bliley) Takeovers by the major banks led to a depersonalization of the mortgage market causing great damage to community values. Mortgages, after this change, are predominantly handled by major interstate banks with no ties to any local community.

6.2 *Voting Rights*

Subsequently, the Supreme Court *Citizens United* Decision (See: Citizens United v. FEC) put an end to equal voting rights. Major donors and corporations could "buy" as many votes as they chose. This has led to, in a worst case, Peter Thiel buying votes for Trump and for Trump supporters. He also provides financial support to the Proud Boys (See: Proud Boys.). Thiel has stated that Democracy is dead. And, in any case, only white males should have the right to vote. He continues this mission.

There has been a long-standing concern of to what extent the Government can enforce or encourage "good behavior". An obvious example is the Environmental Protection Agency (EPA). Conservatives on the Court have argued that the Government cannot legislate or encourage good behavior.

Most recently this view was expressed when the Court decided that Biden did not have the authority to cancel student loans. See the Supreme Court ruling: Student Loans. It took some time but it has been widely recognized that student loans were a very bad idea. Biden was just trying right a wrong. It would seem that this was a serious error by the Court. See Section 13.6. Of course, defining "good behavior" is difficult. But, declaring that the government cannot play a role in nor encourage "good behavior" seems perverse. Few would argue that the government must not take an extensive role in discouraging bad behavior.

6.3 *Fairness and Home Life*

In this age income distribution had been fair, bankers were your neighbors due to the Taft-Hartly Act. Therefore, many had access to a secure home. Teachers were respected and fairly paid, schools were supported and education was widely available on terms available to all who were willing and able regardless of financial resources.

And, most importantly, family units lived a shared life. Typically a main source of shared experience was watching TV and participating in shared visits and trips.

7

New Physical Measurement Methods

During this same period there was a fundamental transition of the technology for making physical measurements. Initially measurements were all marked as lengths or written as numbers to represent length, weight, etc. These were all analog in the sense that they were a sample of the measured value taken at a specific time and recorded on some physical medium. These were imprecise despite very careful and difficult steps. Typically, an error estimate was produced usually in the form ±<error estimate>.

By the end of this period measurements had predominantly been transformed to being recorded in digital form with, usually, an appropriate number of digits.

While noise still exists in all physical systems, the digital methods provided a fundamental improvement. And, it was and is, at least for "static" measurements quite simple to repeat the recording any number of times in order to assess and improve the accuracy.

The analog to digital conversion was fundamental to the advancement of scientific knowledge. Babbage foresaw and made use of this development. And this motivated his development of his digital computer. In any case, Babbage's contributions have been essential to Engineering, Instrumentation, and more. This is fully described in his autobiography (3). It is odd to find that none of the commentators concerning Babbage and his works seem to have read his autobiography. It was just recently republished by Cambridge in its relatively new *Cambridge Library Collection* which has republished important works by means of image enhancement of copies of the original first editions. This has avoided new typographical errors and greatly enhanced the image quality. This shows Cambridge Press at its best, as usual!

8

Publication of Academic works

Wide dissemination of scientific knowledge is essential to the advancement of knowledge. However, controls are needed in order to provide incentives to the authors. At one end of the scale Princeton Press restricts unpaid access to all of its publications using the most recent extensions to the period of copyright to all of their publications. It appears that nothing that they have published is free of copyright restriction. Princeton Press authors cannot distribute PDF copies of their own work without full payment for each copy.

Princeton University has made outstanding improvements in their handling of access for students by, for instance, opting out of the student loan program. Sadly, they allow the University Press to be opposed to wider dissemination of knowledge. However, few scientific or engineering publications appear through the Princeton Press. It was exceptional that they published von Neumann and Morgenstern's *Theory of Games and Economic Behavior*(51).

On the other hand Cambridge Press has a policy which allows authors using a book that they have been writing for a course to also allow students to freely refer to and download PDF copies for the course text. When I discussed this with a Cambridge Press staff member they reported that this was fine with them and they found that this also increased the sales of hard-copy editions of the book. Reading a "real" book is still a pleasure.

9

Life in the Post War Period

9.1 Montreux

Our move to Switzerland in 1947 was due to the fact that my father had decided to remain in Germany after the end of the war in order to work in the Military Government and subsequently in the High Commission for Germany. Switzerland was chosen for us as Germany was not yet safe for dependents and not yet safe at all.

My mother chose Montreux likely due to the nearby Chateau de Chillon, and its connection with the romantic poets.

After our arrival, as usual, my mother dropped me off at the nearest school which was the College de Montreux. At first there was a minor problem since the person who met me at the door did not speak English. At that time I was not really aware of other languages. But, an English teacher showed up and things got straightened out: I was assigned to the right classes by age. I then discovered that I was taking Latin and German being taught in French. I was not allowed to take the English course as it was claimed that I would have an "unfair" advantage.

One other surprise in these early days: I thought that I could learn the vocabulary assignment in the German course by memorizing which French word matched the German word without knowing what ether meant. But, this failed. I first had to lookup what the word meant in English. There still seems to be no explanation of why this should be.

My French improved and things were looking up until the first snow fell. It was then discovered that I knew nothing about skiing. This was worse than not speaking French.

However, by a miraculous coincidence the book by Émile Allais, *La Méthode Française de Ski* (1) had just been published and I bought a copy. This became my bible, and my skiing improved quickly. In the second year I ranked first in the downhill competition. All due to Allais. His key message is "ski in harmony with the mountain" and ski every minute that it is possible, even at night if there is sufficient moonlight!

Allais' book is now quite rare but a copy is available on the Internet Archive at: Allais' method!.

Much later I found this to be an important principle of physics: the *Minimum Work Principle*. Allais expressed the same principle as: "ski in harmony with the mountain". [1] In physics this is best explained by Richard Feynman. See *The Feynman lectures* Volume II, ch. 19 at: [https://www.feynmanlectures.caltech.edu/II_19.html].

[1] How to learn to ski and learn some physics: "ski in harmony with the mountain"

Finally, a key element of this approach to skiing and life is that it achieves best results, but not in any sense competing against others.

9.2 *Before the Start of German Recovery*

9.2.1 *General George Patton*

During this time my father arranged a Press interview with General Patton. This started not too well: a reporter asked Patton how he had succeeded in crossing through Northern Europe and reaching the Rhine before the German forces had had time to destroy the bridges. Patton replied "we took no prisoners." Patton then went on to say that he could reach Berlin well before the Russians. This closed the press meeting and the journalists were required not to file reports. I understand that Patton also mentioned that he could continue to Moscow, but this may have been only a rumor. Good idea all the same.

9.2.2 *Recovery of Munich*

At the end of the war my father was assigned command of Munich and surrounding Bavaria.

Air Chief Marshal Sir Arthur Harris (Bomber Harris!) convinced Fredrick Alexander Lindemann, 1st Viscount Cherwell (Cherwell's Wikipedia) of the effectiveness of civilian bombing and he convinced Churchill that it would be militarily effective to extensively bomb

German cities. This caused widespread destruction of many cities. Dresden is often cited as the worst affected, but Munich was also approximately 60% totally destroyed.

This decision was opposed by many other UK and US civilian and military officials, but it went ahead. The fact was clear that the destruction of the cites contributed little mitigation of the war effort and distracted from more useful bombing of factories and military installations such as military air bases. It was found after the war that a number of key military factories continued to run at full capacity up to the end of the war. This included an advanced Messerschmidt jet aircraft manufactured in a tunnel in the Alps.

9.2.3 Munich Reconstruction

It was my father's decision, opposed by others who preferred rebuilding from ground up, that Munich should be rebuild as closely as possible to what it was prior to the war.

Also, my father attended the Nuremberg Trials as a reporter. Privately, he reported that the trial was not well managed by the prosecution. At least we won the war!

9.2.4 Early visits to Germany

During this time while we still lived in Montreux we spent a period during each of the Summers of 1947 and 1948 in Bavaria. This was only possible due to the fact that my father was the commanding officer for Bavaria. Otherwise dependents were not allowed. Conditions were still difficult, but we enjoyed the time including an extended stay in Göring's previous Summer Residence near Tegernesee. Of course, my father, having full authority, made many things quite easy and fairly safe as long as we were under suitable armed military protection.

9.2.5 Delayed Start of Recovery

The war in Europe ended on 2 September 1945 but the recovery as planned by the Marshall Plan was only started on April 3, 1948 after long delay in the passage through Congress. Due to this more than three year delay there was little progress in recovery. Food was scarce and only obtainable on the barter market. The main "currency" in the

barter market was goods or cigarettes as a currency substitute.

A few cartons of cigarettes were the price for a complete set of old Meissen china.

An instructive incident in Berlin was the use of lighter flints as currency. The flints were in scarce supply so a stable exchange value worked for a period. But, some creative person discovered that they could saw bicycle wheel spokes into short pieces which looked like flints. As a result the market collapsed and the discoverer got rich. Such tricks happen in our time too, especially in "Silicon Valley".

The currency reform only took place in 1949.

9.2.6 Coming to Life

One quite surprising addition as soon as the occupation stabilized was the establishment of the the US Armed Forces network (AFN) which broadcast intended for the occupying forces. The first broadcast took place in April 1945. All broadcasting was in English and there was some political news, US sports reporting and most importantly US popular music and Jazz. The jazz was most popular among the US troops but also among younger Germans. I remember it well and still remember some of the favorites! Of course, I built the radio that I used for listening.

The information about the station can be viewed at: AFN Munich

9.3 Initiation of Recovery: 1949

Seeing Munich before the 1949 beginning of recovery when there were just paths plowed through the ruble where streets had been was a distressing sight.

When the High Commission for Germany was established in 1949 my father became the administrator for Munich and surrounding areas. He reported to John J. McCloy who was the American High Commissioner for Occupied (Western) Germany from September 1949 to August 1952. McCloy's office was in Bonn.

Conditions in Germany began to improve by the Summer of 1949 and we moved to Munich. At this time the Military Government was just ending and turning power over to the High Commission

for Germany. And, the denazification program was deemed to be substantially complete within West Germany.

While in Munich I experienced the horrors of the war and its aftermath. Repeated visits to Dachau are permanently in my memory.

I also remember some of the rules which were put in place by the US military: examples included segregation of buses, and train carriages and only allied forces were allowed to drive on weekends.

Our home, like the others acquired for US occupation families, was obtained by military police choosing what seemed suitable homes and giving the resident families 24 hours to move out, leaving all furnishings behind and taking one suitcase each.

Policing was difficult. Only the US Military Police had any authority over US military personnel and their families. So, US military and dependents could do as they pleased. This was not always helpful. I chose not to associate with this aspect of the community and only occasionally attended the US school. In addition, due to my father's position all of our family had diplomatic passports. This was very convenient when traveling generally and when crossing borders since it was not necessary to wait in any queue nor submit to any checks.

9.3.1 Conditions in Austria

However, there was, in effect, no denazification program in Austria as it was declared, by the Austrian former Nazi politicians, to have been an "occupied" country. This had consequences that I learned more about only later. In any case, this meant that the government bureaucrats all of whom chose to be Nazis, retained their positions and have continued up to retirement. And, of course, "friends" have taken their positions.

For example see: Waldheim Affair. It has also been alleged that Waldheim was responsible for the transport of Jews from Eastern Europe to Dachau (See: Dachau) and he must have known about Mauthausen. (See: Mauthausen).

9.4 German Recovery and the Marshall Plan

The start of the Marshall Plan was delayed by more than three years from the end of the war due to the difficultly in getting it passed due to political conflict in Washington. During this time there was practi-

cally no relief for the German population. Starvation was widespread. It took an extreme effort by Marshall , Kennan, and others, against strong opposition, to finally gain approval. The main alternative was the Morgenthau plan which would require destruction of all industry in Germany and reduce the country to an agricultural economy. Morgenthau had played a prominent role in FDR's recovery from the depression, but this was not a good choice and it was finally defeated.

During the intervening years there was little progress in recovery so food was scarce and only obtainable on the barter market. The "currency" in the barter market was goods or cigarettes as a currency substitute. An instructive incident was the use of lighter flints as currency in Berlin. The flints were in scarce supply so the exchange value worked for a period. But, some creative person discovered that they could saw bicycle spokes into short pieces which looked like flints.

As a result the market collapsed.

The currency reform only took place in 1949.

My father decided that Munich should be as best possible restored rather than, as initially planned, flattened and rebuilt as a modern city. He was useful in many other ways. He was very active in the reestablishment of political and social organizations. This included, somewhat separately, membership in the TurmFalkenindexTurmFalken This was a leading social association which still continues to exist and is prominent in the pre–Lent Fasching activities. He was also elected Prince of the Octoberfest (he got to lead the band!), and had many other civic duties. He was awarded the Bavarian "EhrenKreuz". (See: Bavarian Order of Merit This was a very high honor and it provided free entry to all public buildings, Museums, castles, etc. and was immediately recognized if we approached any state properties. My father did enjoy being honored in this way.

There was an extended period after the end of the war when he was highly regarded, even revered, by many in Munich. He was called on for all important ceremonies and events. For a time he had a TV show and appeared on other "celebrity" shows.

It was also planned that a street in Munich would be named after him after his death, but it seems that he outlived that recognition.

However, the administration of Germany until transfer of civil authority under John McCloy was not perfectly smooth. I learned from my father one incident that indicated some of the frictions. An official holding a position similar to my father's established the procedure

when he met with appointed German officials. As a fixed rule he sat at his desk facing out of the window behind his desk so that his back was to the officials. He announced his orders and dismissed them without once seeing any of them.

In addition there were many rules imposed on the German population by the military government. These included no use of vehicles on the roads on weekends, separate carriages on all trains and other public transport which were exclusively for US personnel. Typically many of the carriages were for US use only. This was regardless of when they were empty and the other few carriages were full.

9.5 US Air Forces use of Poltava, Ukraine

Another aspect of the war which has been given little attention was the American Air-force activities in Eastern Europe. A major purpose of these activities was to provide logistics support for the American bombers which mainly flew from England. The establishment of airfields in Eastern Europe permitted the bombers to bomb their targets, continue to an airbase in the East, refuel, and reload and use the return to England as another bombing run, thus doubling the bombing effect. This activity is very well presented in the book *The Poltava Affair* by Glenn Infield (26). And, the book is still in print and on Amazon. (The Amazon Summary is quite inaccurate.) These bases were also used as transit stops for W. Averell Harriman and others on trips to and from Moscow. It is surprising that this has not gotten more attention. In any case, a fascinating story.

I only learned of this important activity through a close friend Jean Baudrand who seems to know a great many more otherwise little known subjects!

9.6 Serious Skiing

As mentioned above I first learned to ski[1] in Switzerland, but then took up skiing more seriously after moving to Munich.

[1] Skiing: exactly as explained by Émile Allais.

Formal schooling in Munich was in any case not available on terms that I found acceptable so I had the opportunity to spend time on other pursuits.

By 1951 I was participating in alpine racing on a full–time basis. A

member of the German National ski system had approached me and asked: do you really want to be in Alpine ski racing. I answered immediately: NO, that is the only thing I want. So I became a member of the German National team. I competed in the Alpine events: downhill and slalom, with strong preference for downhill.

The home base for the German ski team was Garmisch–Partenkirchen. We traveled mainly in Germany and Austria for race meetings.

As I had learned in Montreux, I followed Allais' method as exactly as I could. See Allais' book: (1). The key to Allais' method is: *ski in harmony with the mountain*.

This, rephrased in scientific terms is "the Minimum Work Principle". It is of fundamental significance and widely used.

For the best explanation of the principle see Feynman at Feynman Lectures, specifically the Chapter: Vol–II, Ch. 19. It was my good luck to learn about it so early. Also, much later Ed Tufte(48) referenced Allais' book as an outstanding example of effective graphical presentation. It worked for me.

I continued to follow Émile Allais' prescriptions to the letter. This included starting skiing each day at first light and continuing as long as feasible. Since I was part of the Downhill Group, training usually consisted in running practice runs on the Olympic downhill course on the Kreuzeck mountain. This course was used for the 1936 Winter Olympics. The course no longer exists mainly, it appears, due to the fact that it was never greatly widened with trees removed to allow "good" TV coverage.

During this period I was called on to evaluate new ski equipment. In particular I tested the Marker toe–release bindings which allowed release under excessive rotational force to cause the boot to rotate, rather than causing a spiral fracture of the lower leg.

Also, for downhill and even recreational skiing I chose Laupheimer Starfighter skis. These were unique in that they were not only concave along the length of the ski, but were also slightly concave across the ski. This had the feature that on a hard surface only the ski edges touched the surface. While this meant that they tended to cause "catching an edge" when attempting a turn, they tracked without side movement, this was particularly helpful at high speeds. Just what I wanted! The ski company name still shows up on the web, but they are long out of business.

A memorable moment at this time occurred when I was standing at the side of the Olympic downhill course on the Kreuzeck during practice runs for a competition. I just happened to look up the course at a difficult section as Zeno Colò came though the section *without making a sound!*. This proved Allais's principle and was an amazing technical feat. On the race day, he won. Trying to apply the same principle helped in improving my ranking. This continued to be essential to my adopted "method."

Unlike my teammates I substantially survived the seasons without serious injury. I was the only one who never had to be brought down by rescue sled. This, despite some spectacular crashes! My teammates and friends were not so lucky.

The training days that were most fun were the "non–stop" downhill days. This meant running the full course at near race speed, and immediately taking the cable–car back up, and repeating this loop until the last cable–car run in the day. Film recording and timing data were kept for review. By about midday it was necessary to lie down flat in the cable car on the way back up in order to recover some strength.

One added feature to my participation in the German team was that since I was American I had privileged access to the lifts, specifically the cable car which ran up to the upper station on the Kreuzeck mountain. The rule was that Americans entered first through a separate entrance. Then if any room was left others could enter. I explained that my teammates were with me and therefore we could all use the American entrance.

The home base for the German ski team was at the top of the Kreuzeck. All of the equipment and accommodation was there. For race meetings we traveled mainly in Germany and Austria.

9.7 Change of Plans

During the Summer of 1952 my family in Munich was breaking up with my sister leaving for school in the US and my mother also deciding to return the US. I assumed that I would continue my skiing career.

However, at this time a person (I assume that this was someone from the US State Department.) happened to visit my father and my name must have been mentioned. So, he talked with me and said "you really should consider formal education, and I recommend Deerfield Academy".

This seemed like considered advice, but I thought no more about it. However, few weeks later an information package, including an offer of admission, arrived from Deerfield Academy! I read through the material carefully and made a fundamental change of plan: I would retire from full–time skiing and go to Deerfield.

Incidentally, John McCloy's son, John J. McCloy II was also a classmate of mine at Deerfield. We both returned from Germany in the same year in order to attend Deerfield.

9.8 Close of Serious Skiing

My focus on serious competitive skiing ended when I was 15. I resumed skiing again later and Ilse and I continue to enjoy skiing particularly at our "old" resorts in Austria and whenever possible, at Mad River Glen in Vermont. Mad River Glen is a private resort and we are members. The website is: Mad River Glen

Sadly, Garmisch, which hosted the 1936 Winter Olympics, has faded quite a bit. The Olympic downhill course (on the Kreuzeck mountain) is gone. The course was seriously challenging, but could not be seen from TV cameras. However, a webcam of the mountain is available at: Garmisch-Partenkirchen

9.9 People and New Events

My early life can be described by borrowing from Holiday Golightly: Traveling.[1] And, this has led to the opportunity to meet people of widely differing backgrounds, and to be influenced in many ways.

[1] Traveling in another age to other places.

During the seasons when skiing was not possible most of my time was spent reading technical and mathematical material and building model airplanes, trains, and radios and a pulse jet propelled model airplane. But this also included learning enough geometry to draw contour maps so that I could draw interesting ski slopes and set slalom courses on paper.

However I also came across an article about Lee DuBridge and Caltech and thought that if I did ever decide to go to a University, that would be the right place.

It appears that being on my own was beneficial. And, this seems not

to be unusual. Each person has their own way of thinking and acting and this, of course, changes with age. I was allowed to take advantage of this but, sadly, many others do not have the opportunity to choose.

10

Deerfield Academy

In the Fall of 1952 I traveled with my mother from Munich to New York where she took me to Grand Central Station and said: Be sure to get on the train marked for Deerfield. (deerfield.edu). This was the usual means for many of the Deerfield students to come and go each term. The train made a special stop quite near Deerfield at the start and end of each term.

The Headmaster had a firm rule that students could not arrive privately and only at the specified date. Only if there was some extreme necessity was an an alternate allowed. Many of the students lived in or near New York city in any case but others were brought to New York to catch the train with the rest.

10.1 Frank Boyden

Frank Boyden, the Deerfield Headmaster, accepted me at Deerfield and transformed my life. He even agreed, despite the usual rules (of course, he made all the rules!), that I could have a few weekends away during the Winter in order to participate in skiing competitions within relatively short distance from Deerfield. This meant ski areas in Vermont and New Hampshire. He only asked; "Do you think that you could win?" I admitted that it was not likely due to the limited time that I had for practice, but I would certainly try! So, I got permission.

It was mentioned, at a later date and under strict confidence, that I was accepted at Deerfield Academy on a full scholarship for the three years. No one was available to pay the tuition. The Headmaster had firm rules that were intended to ensure that all students were treated fairly. Thus, no one knew if anyone was on a scholarship. Actually, as the headmaster managed such matters there was no scholarship

program as such. I was treated in exactly the same way as the other students.

At start of term all students coming from the New York City area took the same train from Grand Central Station which made a special stop at the otherwise unused Deerfield Station. And they departed by the same means back to Grand Central. This included Steve Rockefeller and Fritz Maytag, while I was there. In any case, parents were not allowed bring or pick up their children to or from the Campus. In addition, no cars with parents or otherwise were allowed on the Campus at any time.

Deerfield was a great benefit for me. This included the usual academic studies but also much more. The teachers tended to encourage careful thinking. And, the Headmaster instilled a sense of responsibility that became compelling.

This was also instilled in a remarkable book by one of the teachers, Robert McGlynn.. The book, *10 Trail Street*(31) is still available through used book dealers.

10.2 SAT Exams

All students were provided example SAT tests from the Educational Testing Service located in Princeton. These were, for me, essentially a game. My main purpose was to attempt to complete each exam in the minimum time. I nearly always chose correct answers for all the questions. The challenge was to find the quickest way. For this, I first noticed that the right answer was more often toward the right in the list of answer choices. Then I checked if the right answer had to obey some simple rule, such as a positive integer less than some value. It fairly often happened that there was only one such number in the list of choices. That allowed me to move on the the next question right away.

This, and other similar observations meant that I usually finished a three hour exam in well under two hours. Only once did I realize as I walked out of the exam room that I had checked a wrong box. The exams have been improved since then. This has been in part due to the fact that John Tukey took me along when he did his periodic consulting visit to the Educational Testing Service ETS Princeton in Princeton. On our first visit there was some alarm at my description of how I always got perfect scores in record time. They did make changes, but it seems to me that the exams are still more a game than a test of

serious knowledge or intellectual ability.

10.3 Summer jobs

During the Summers at Deerfield I found temporary jobs in order to pay incidental bills but including, of course, help with costs of skiing.

One of these jobs had substantial value with respect to the organization and economics of business enterprises as well as providing income.[1]

[1] As Henry Jacobs learned when interviewing an economist about her important theory: He asked: Does your theory apply in Iran, for example? The answer was: No, it applies more in general than in any specific case!

This job involved working in a local pickle factory. The work flow was quite simple: harvested cucumbers arrived and were dumped into large salt water vats. They were left to ferment at which time they were fed though processing and onto a conveyor belt to be funneled into jars. The jars only differed by size. Next the labels were attached to each jar. Which label was used was determined by the received orders. Some days there were committed orders for, say 500 jars of extra fine kosher pickles, or on other days Safeway's "garden fresh extra fine juicy hand picked...", etc. Only the labels changed. The pickles all came from the same sources and same vats. The "kosher" pickles were picked up by a Rabbi who ordered a number of boxes of pickles and paid for one box less than the number "purchased".

When I looked into the storeroom where the labels were kept (usually locked) I counted at least 30 labels showing differing brands and types.

However, another opportunity arose in the pickle factory. I had noticed the forklift vehicle used to load the boxes into waiting trucks. The job was to place and load the forklift so that the correct collection of boxes could be loaded into the waiting truck at the end of the loading dock. This went pretty smoothly until the driver arrived in a drunken state. Quite soon he drove the forklift off the end of the dock. He was fired and I quickly volunteered for the job. Much more fun than cleaning the pickle vats!

Later, at Princeton, I told this story to an undergraduate class. This led to some discussion within the Economics Department.

10.4 Final Days at Deerfield

From Deerfield I applied to the California Institute of Technology. In order to satisfy some of the faculty at Deerfield I also applied to MIT. I was accepted at Caltech, MIT, and Dartmouth where the ski coach sent an acceptance letter including a full scholarship.

While still in Munich I had read about Caltech in Time Magazine (Lea DuBridge was on the cover) and it seemed the only choice for me should I consider some formal education.

It was the standard practice at Caltech that a faculty member showed up at Deerfield to interview me. This confirmed in my mind that this was the right choice. However, it appeared that the Caltech professor was also interested in talking with Frank Boyden. They were close friends. This just reinforced my view that Caltech was the right choice.

It was also helpful that Caltech took the review of each applicant by a faculty member a lot more seriously than looking at SAT scores. I was offered a full scholarship. This was essential as I had no other support.

10.4.1 An aside about the value of athletics

The 1936 Winter Olympics were held in Garmisch, but there were some political tensions. Specifically one of the key members of the German ice hockey team (the goalie, in fact) was Jewish and had already left for France. After difficult negotiations with Hermann Göring it was agreed that he could safely return for the Games as this would increase the chances of Germany wining the ice hockey event!

10.5 End of Competitive Skiing

However, during my time at Deerfield I had some skiing opportunities, particularly greatly helped by Al and Nancy Clark who ran an Inn near Mad River Glenn Glen. They took me in as a guest, helper and in effect family member. Al worked at Mad River and ran the ski patrol and I helped with that as well as helping in the kitchen and general cleaning. Great times!

Mad River Glen was founded in 1947 by Roland Palmedo See: Roland Palmedo on Wikipedia. It has maintained its original character

and is now owned by a consortium which is dedicated to maintaining it "as it was." We are members.

This was about the time that Harriman founded Sun Valley. This joined the already established Alta in Utah as one of the most important resorts in the US in the immediate post-war period. Alf Engen in 1935 first hiked into the Alta mountains and reported that this would be an excellent ski area. The first lift was installed in 1937!

In addition to skiing at Mad River at Easter the Clarks took me along on their annual trip to Mount Washington. This mountain is the highest mountain in the Eastern US. There are no lifts, only an environmental test station at the totally treeless top. Trees only appear down where the mountain basin flattens out.

Even in Spring it is extremely cold and skiing the Headwall is initially a a 60 degree slope down to the more gentle basin and on into the valley. The start at the top of the mountain is a bit worrying: only the valley below can be seen. The face of the Headwall is not visible until you push off over the edge! I skied the Headwall and made it down! When traversing, one's shoulder brushed the snow! Not a good idea to fall!

Much later Ilse and I met with the Clarks whenever we were at Mad River. All good times and memories!

10.5.1 One Health Incident

I returned to Deerfield for my final year and began intense exercise in preparation for skiing. However I noticed that my legs were going numb. This continued to worsen and I was examined at a Hospital in Boston. There it was discovered that I had fractured and fused my 3rd and 4th lumbar vertebrae. I then recalled that I had, during the previous winter, encountered a tree while skiing the Fall Line at Mad River. This had been somewhat painful but I skied down and the pain subsided. This was not the tree's fault: I caught an edge when starting a turn at the top of a steep ledge!

However, this reduced my back mobility and the subsequent extensive running had aggravated the injury. The Lahey doctors recommended surgery to separate the vertebrae. This did not seem a good idea to me and I said that all I really needed was to to be able to ski in competition for my final year at Deerfield. The doctors ridiculed this plan. But I also discovered that the cause of the aggravation was my

extensive running. So, I ran much less and the numbness finally went away. The main lasting effect has been that I could no longer bend from the waist and touch my hands flat on the floor! Previously I could do this easily without any warm-up.

I had a good winter of skiing which, as I knew, would be my last as a competitor.

Later on, after completing my PhD I took up skiing again and Ilse and I continue to enjoy skiing together. She ranked second in skiing in her school!

11

California Institute of Technology

From Deerfield I applied to the California Institute of Technology as I had long considered this to be the right choice. In order to satisfy some of the faculty at Deerfield I also applied to MIT. I was accepted at Caltech, MIT, and Dartmouth . From Dartmouth the ski coach sent me an acceptance letter.

Obviously, I accepted Caltech. My only regret was that this definitely put an end to a serious level of competitive skiing.

11.1 Early Days

Caltech started with a number of surprises. The key was to pass the exams at the end of each term. Some students attended most lectures. I chose to concentrate on learning how to solve the problems from previous exams. The solution techniques varied little from year to year.

Unexpectedly, very early in the first term I was approached by a member of the Humanities Division. This concerned a student who had lived in East L.A. (For information, East L.A. was and is a pretty tough community.) The student involved was admitted based on a phone call from one of his teachers to a Caltech faculty member. The teacher reported that this student had been "difficult", often absent and only rode in and out on his motorcycle. However, he seemed to understand a lot about math and physics when he did appear at school.

So, a Caltech faculty member braved the challenge of driving in East L.A. and met with the student. The student's ability seemed to be confirmed and so he was admitted. However, when he arrived it became clear to the Humanities folks[1] that the student simply did not know how to write a sentence or otherwise to express himself in writing.

[1] Several of the Humanities Division faculty were from East Coast Ivy league Schools where they had been made uncomfortable due to their political views. They also knew about Deerfield Academy and felt that I must have had good preparation there.

So, I was asked if I could help with some tuition. Luckily I had known similar folks in Munich so we got along pretty well. He somewhat grudgingly accepted that he would need, at some times, to express his knowledge in writing. He went on in physics, with encouragement from Feynman, and completed a PhD. And, I was told later that he continued to carry out significant work.

11.2 Pauling's Chemistry Course

A first classroom surprise was the chemistry course taught by Linus Pauling. It was encouraging to find that the assigned text was his recently published chemistry text. As it happened I had taken the advanced chemistry course at Deerfield taught by Helen Boyden, an exceptional teacher, using this same text (38).

So, it was natural to assume that this background would provide some help. However when the first problem assignment was handed out I was stunned to find that I could not solve any of the problems. As far as I could remember I had never encountered any course problem that I could not solve. So, in some panic, I ran to the chemistry building and asked the first person there if anyone could help. They pointed to an open door to an office with the comment "I think that he might be able to help." On entering the office there was Linus Pauling. He welcomed me and fully explained the appropriate method for solving each of the problems, and he also mentioned that the assigned textbook was meant as "background" reading, not as what he would be teaching which was substantially quantum chemistry.

There was no choice but to try to do well in the course.

11.3 More about Pauling

I had the opportunity to meet Pauling on other occasions and he described his concerns about the nuclear weapons testing above the Nevada farm lands.

In addition to the direct radiation effects his additional objection was due to the fact that the radiation in the atmosphere was carried by rain which concentrated it through plants as eaten by cow herds and thus into the milk as sold in stores. This particularly affected children. Of course, the military had not thought of the concentration effect. And, in particular, that the milk was consumed by many children. This surely

had more serious negative health effects.

Due to hostility from the military community and the McCarthy Senate hearings this had led to Pauling's passport being withdrawn by the State Department. For this reason he had to decline any visits outside the US. He did this without reference to his passport problem until he was awarded a Nobel Prize for chemistry. . He said that he at first thought to mention that he could not accept the prize since he was not allowed a passport which would permit him to attend the ceremony in Stockholm. But, he said that he would write just one more letter to the State Department asking if he could have his passport back. This worked and he got his passport quite promptly. He did not embarrass anyone by publicly explaining the circumstances at the time. Also, he was (I think that this is still true) the only person to be awarded two Nobel Prizes: one for Chemistry and another for Peace.

11.4 More Good News: Meeting Lee DuBridge

The Caltech community continued to provide exceptional experiences. A prominent feature was getting to know Lee DuBridge See: Caltech Library entry: Lee DuBridge.

His capability and leadership reminded me of Frank Boyden. A reason for getting to know DuBridge was my activity in the student government. This made me responsible for keeping him informed of relevant student activities, particularly ones which might give rise to problems.

Most of these were fairly minor pranks but in one case an FBI agent was punished in the usual way for acting in conflict with rules of conduct in one of the student Houses. The student house that was involved was Ricketts House where I was also a member. The punishment was that the guilty party was thrown in one of the house showers with the cold water running. The FBI agent was clearly guilty and so was suitably punished. This escalated up to Hoover at the FBI and some quite extreme threats were made, specifically directed at me. Three FBI agents made an appointment and appeared at my office. They made a number of threats, and I looked as attentive as I could. But fairly soon I said that I guessed that the meeting should be over as I had nothing to say about the alleged incident. But, I advised the agents against walking near Ricketts House on the way out.

I had, of course, presented the facts to DuBridge. This time I was

definitely worried about his reaction. He simply said "I will take care of it". And, I seemed to see glimpse a smile! It did take some effort, but he fixed it. This required DuBridge to contact Eisenhower. DuBridge was Eisenhower's Science advisor. I am not sure if it was relevant, but my father was also a close friend of Eisenhower.

11.5 Student Affairs

An important part of my Caltech experience was my interest in student welfare and activities. Initially I was elected to the Student Board of Control to serve in my second year. This organization held the responsibility to ensure that the student code of conduct was followed. The code of conduct was, and is, quite simple: *No student shall take unfair advantage of another student*. Subsequently I was elected Vice President and then President of the *Associated Students of the California Institute of Technology* (ASCIT). This organization had legal status as a non-profit corporation under California law.

11.5.1 Board of Control

It was during my first year that I was elected to the Board of Control. And due to other activities, including in my final year as ASCIT President, I served for the following 3 years. At the first meeting I mentioned that I would not favor any form of punishment. I had read enough of the relevant literature and faced relevant experiences to convince me of this principle. I was able to convince the other members of the BOC as well.

An early experience that affected my thinking was the condition in Germany almost immediately after the end of WW2. This came about due to the fact that my father was the Military Commander for Southern Germany under the US military occupation. Initially my mother and sister and I lived in Switzerland for obvious safety reasons. But we paid short visits to Bavaria in the Summers before it was relatively safe to move to a home in Munich. During this time I learned quite a bit about Crime and Punishment at first hand and later from relevant literature.

Based on this background I made clear, when I was at Caltech, that I would not support any direct punishment. This was easy in most cases which involved some form of cheating on exams. We had about 5 or 6 such cases and it was quite clear that the student realized that they had done something clearly wrong, but they also usually admitted that it

had done little to improve their performance on the exam in any case. They were excused on the commitment not to repeat any new offenses. A subsequent questionnaire sent to all students in my graduating year seemed to indicate that the choices made by the BOC were appropriate.

The purpose was to protect the rights and privileges of everyone. If someone acted in a manner that was not consistent with this we had the obligation to find a fair resolution. A common case was a student who had in some way cheated on an exam. This almost always meant that they had asked another student about their solution of one of the questions and then used that information. Rarely did this actually do any good and typically the student apologized.

There were a few more serious cases. The most worrying case was a student who was, we understood, wanted by the Pasadena Police as a suspect in a burglary. He had apparently also done other things which were not consistent with the Honor Code. He was open to a full discussion of his relevant activities but also he stated that he did not wish to continue as a Caltech student. He did want to reform and study in a much different and less strongly focused on scientific or as challenging an environment. Aside from trying to find a fair resolution within the Caltech community we had to consider the Police report. It was our belief that the student was very likely the person identified by the Police, but this was not unquestionably certain. One obvious choice was to provide the name to the Police and let them pursue the matter. Our decision was to allow the student to resign from Caltech and pursue educational opportunities elsewhere.

Subsequent evidence indicated that this was a successful outcome. In several other cases the student admitted that the pressure of work had overwhelmed them and they felt unable to "keep up". And, they also admitted that they would prefer to transfer to a school where the demands for science and technical work were less. This was supported and proved to be successful.

However, the pressures of work for the undergraduates at Caltech were, and apparently still are, quite extreme. Some students found that they would be better off in another environment. We always helped to facilitate a student to transfer to an environment which they would find more suitable to their interests and skills.

11.6 Feynman Physics

My most prominent initial experience was taking an informal physics course from Feynman. In my first year, 1955, an announcement was posted saying that anyone who wanted to could attend lectures by Feynman instead of the usual Physics I course lectures. However, it would still be a requirement that these students take the standard Physics I exams. About 20 students showed up for the first Feynman lecture. Feynman arrived with no notes. But, he noticed that one of the students was preparing to write notes in his notebook. Feynman said: "Put that away, you cannot listen to me and take notes at the same time." The effect of that was that only about 5 of us continued with the lectures. Feynman continued, each meeting without notes, but ending exactly on time and at an appropriate point. It appeared that he did this somehow spontaneously. However, later I learned that he rehearsed each lecture very carefully. When he later gave the First and Second year lectures he obviously relaxed the "no notes" rule.

I also got to know him well enough to seek his advice on career choices, and to learn a lot in any case.

Feynman was awarded the Nobel Prize in Physics in 1965. There is some controversy about this. It was known by Feynman that the LA Times had announced the award before he was informed. It has been reported that Feynman said that if he had been informed before any public announcement he would have refused the Prize. But, he felt that it would be difficult for the Nobel awards people if they had to publicly retract his name and only award the prize to Tomonaga and Schwinger. This shows what seems to be an important truth: Feynman was strongly opposed to awards of this kind but he was also sensitive to the views and concerns of others.

11.6.1 Heisenburg's Role

Subsequently Heisenberg attempted to claim that he had purposely stated a wrong critical value for the nuclear explosion. This was shown to be false due to the, unknown to him, recordings of his statements while interred in the UK.

However, he also did not mention that he had insisted on taking charge of the German nuclear weapons development program and report directly to Hitler. Since his incorrect value for the required critical mass was hugely larger than the correct value he proposed

building a very large ship to carry the bomb across to the US East Coast.

Feynman was sensitive to what he saw as inappropriate behavior. This was made clear when, by some possibly careless accident, Heisenberg was invited to give a talk in the Physics Department. I happened to meet Feynman as he was walking to the seminar. He mentioned that Heisenberg was the speaker. I joined him and we took seats in the front row. Only a short time into the talk Feynman spoke clearly: "This is a load of bullshit". He then walked out and I left with him.

Refusal to accept dishonesty is not a form of intolerance.

11.7 More Great Teaching Experiences

Other exceptional teachers were Frank Marble and Frank Press.[2] See Marble news at: www.caltech.edu/about/news/frank-e-marble-43440 or See Marble history at: https://oralhistories.library.caltech.edu/138/

[2] Exceptions to my usual lack of attendance at lectures

Marble taught a thermodynamics course and I attended every lecture. The first remarkable feature of this course was the organization of the blackboard. Text was written with Sections properly indexed. Thus each numbered equation could be later referred to as needed. The equation numbering showed the lecture number and the equation number within the lecture.

This continued through to the end of the course. And, references to previous equations were given by the equation number. Somehow he kept all this perfectly organized and it was a great help in mastering the material.

As an additional event a few times he announced that he could not give the next lecture as he was needed at Cape Canaveral to ensure the correct functioning of the liquid fueled engines for a test satellite launch.

Only rarely do teaching and doing go so well together!

11.7.1 Geophysics

And, in my senior year I and another student signed up for a new graduate course in geophysics taught by Frank Press. We greatly

enjoyed the course.

This was both fun and very informative. Geology at that time was still mainly the study of rock formations and other descriptive studies. Very little physics was involved. Press had decided to change this by introducing what is now geophysics. Press would fairly often make remarks like "I expect that the undergraduates can understand this right away, but...".

See his page at Caltech: Frank Press.

11.8 Other Study and Research

Initially a job was available in Haagen-Smit's chemistry lab where he was measuring the chemistry of the air the LA basin area. This led to the better understanding of the sources of the air pollution. My job was very simple: every 2 hours the measurement system had to have its data recorded and the instrument reset. Of course, I had the night shift! But, I learned a lot about lab work. My next lab job was with Paul Duwez. He was studying the properties of metal alloys particularly for demanding applications such as for use in high-performance aircraft. This required making measurements in a high vacuum (do to oxidation of the metals) and during controlled temperature variations. So, I got to know how to operate a high performance helium leak detector and learned much more about lab work.

Next was an invitation to do part-time work at Consolidated Electrodynamics (See: Consolidated Electrodynamics). The leaders of this company in the 1950's were closely affiliated with Caltech and JPL. They were Harold Washburn, Cliff Berry (See: Cliff Berry) and Charles Robinson. Initially I worked on modeling the beam behavior of mass spectrometers.

I was also involved in other research and development and filed my first patent. The patent was titled: *Liquid Coating Apparatus,* patent # 2,983,250, Jan. 1958. This patent provided a method for continuously transferring liquid developer to photographic paper as supplied in rolls. This permitted use of the paper roll spooled through a recording oscillograph so that the recorded and displayed results could be studied as they occurred. For example Boeing used these instruments in their flight trials so that they could observe and react to events instead of only seeing the recorded data after the flight landing and data processing was completed.

Boeing was, when I interacted with them, a spectacular company based entirely in Seattle. Everyone knew everyone else including the families. And, everyone was dedicated to building the best airplanes possible. I shared in this environment. Now, since the unsound merger with North American and the unmanageable choice of headquarters in the middle of nowhere (Chicago) they are a danger to themselves and society. And a tragedy easily avoided, if greed had not been the driving force. One of their best airplanes, the 787, based on substantial new technology, seems now at risk.

I was an inventor of the dual-capstan system for reducing tape tension noise in magnetic tape recording systems. This appears to have been invented at several places and never patented. I was surprised when I explained this idea to a group working on the tape systems. They all said that this is nonsense since the trailing, larger, capstan would pull more and more tape until the tape broke, forgetting that the tape is elastic.

This work caused me to be asked to help with other customer installations and operation of the instruments that I had helped to develop. This often required travel to the customer's site to ensure that the instruments functioned correctly and to explain their use to the customer engineers. I hope that this also improved my communication skills!

11.9 Final Days of Loyalty Oaths

When I approached the window where I went to obtain a passport for travel to the London School of Economics I was told that I must sign a loyalty oath. As it happened I had been among the campaigners to have this repealed. And, we had just recently succeeded.

So, when handed the form, I tore it in small pieces and pushed them through the window to the official. He handed over the passport.

11.10 Fit for Purpose

During this period I learned the value of engineering work that is "fit for purpose". Informally, by this is meant that the system will actually and efficiently provide the intended functions. In most cases this also includes safety and ease-of-use. This is relevant in a wide range of contexts: consumer products, industrial equipment, etc. An obvious example that I noticed was the development of a new office workstation

for clerical workers. The prototype looked nice and seemed to be fairly easy-to-use. Except there was no obvious way to turn power on! The power switch was behind the unit and near the floor.

11.11 Final Year at Caltech

In my final year at Caltech I asked advice from various people, most importantly Feynman and DuBridge and also Douglas Logan who was Chancellor of the University of London. He strongly recommended that I attend the London School of Economics and others, particularly Feynman, concurred. This made the choice easy.

Just at this time DuBridge was asked to nominate a student for a grant in order to pay for graduate study. The grant provided a fellowship which fully paid for the entire time of graduate study. This was the *Edward John Noble Foundation Grant*. The foundation had a simple rule: payment for the full cost of graduate education at a "typical" University. By this they obviously meant schools such as Harvard or Princeton! I tried to point out that LSE costs were very much lower, but they said that their rule was fixed. At LSE I tried to be careful about my support. Trips to the Continent were mentioned as necessary to visit my father who was still living in Munich.

12

London School of Economics

12.1 Introductory Requirement

I attempted to register for the graduate program expecting to complete a PhD degree. But since I had no background in economics it was decided that I should take an exam before being formally registered for the PhD.

The chosen exam was the final year economics exam for LSE undergraduates. The undergraduate course was a three year course. So, I studied fairly hard, with much help from Maurice Peston (who had spent some time at Princeton visiting with Oskar Morgenstern). He hoped that I would get a First (this is the top grade on the exam) but I only got an Upper Second (next best). In this exam the hard questions for me were of the form: who was the UK Chancellor of the Exchequer in 1939?

This took a few weeks of study and cleared the way for the formal registration for the PhD degree.

12.2 The Course of Study

I specialized in statistics, mathematical economics and game theory. Crucial to this again was the advice of Maurice Peston (later Professor at Queen Mary College and, as Lord Peston, a Labour member of the House of Lords).

His contact with Oskar Morgenstern provided a very useful introduction to Game Theory and analysis of economic data.[1]

[1] Remember my time while at Deerfield when I worked for a Summer at the Pickle Factory. See 10.3 Summer Jobs.

It was quite unlikely that I would have survived at LSE without Peston's advice, guidance, and support.

12.3 *A Minor Conflict*

I might not have been allowed to continue at LSE had it not been by the intervention of Lionel Robbins, who was the LSE Director. This was due to an incident in Karl Popper's seminar (It had been recommended that I attend the seminar and I went to the first meeting.) During the lecture Popper drew on the blackboard a force balance which he described as "coming to equilibrium due to the equal weights". He then indicated that this apparently had some philosophical significance.

However, the drawn connection of the centers of mass of the weights was above the pivot point. So, I raised my hand and pointed out that in fact the balance was unstable due to this reason and if set to move freely it would soon crash on the floor. I may have added: does this affect your argument?

At this point Popper demanded that I leave the room. As I left I could not resist saying that this was fine with me since nothing was to be learned... Popper then went to Robbins and demanded that I be expelled. Robbins said "that is not the way we do things here."

This was a lively topic of discussion at the school for a time, and Popper did not again appear in the Senior Common Room. Due to this experience Lionel Robbins joined my hero list and I forgot Popper and his nonsense ideas about science.

By the way, a quite simple explanation the stability of physical systems of this kind is described at: Stability Condition. Even Popper might have understood it!

12.4 *An Unusual Lecture*

Another fun experience at LSE took place at a seminar given by Joan Robinson from Cambridge. She discussed current work in Economics at Cambridge and explained some new work by Piero Sraffa. She pointed out that this work was based on some preliminary work by a little-known Austrian economist named John von Neumann. She then described in loose and non-mathematical terms what was informally the von Neumann growth model.

Of course, the von Neumann Growth Model had previously been published in full mathematical detail, initially in German in 1937 and then in English translation in 1945. The English translation titled *A Model of General Economic Equilibrium* appeared in *The Review of Economic Studies* v. 46, pp.1-9, 1945. (See (49)) or The Review of Economic Studies vol.13, Issue 1, 1945.

Also during the talk a student raised a question which included: have you read a paper by author <...>? Robinson answered: "We do not read papers, we write them." At this point I pretty much lost interest.

I also learned that giving a seminar talk at Oxford was best done before lunch. After lunch the Dons were all drunk, and asleep at least to my kind of thoughts. Times seem to have changed by now at least in some of the disciplines.

Obviously, I had come from a more sheltered scientific environment.

12.5 Progress due to Morgenstern & Tukey

I found that I had questions about the methods that I was using in my thesis, but I could not find anyone in the UK who could provide convincing explanations so I sent drafts of my PhD thesis to Morgenstern and Tukey at Princeton. They both answered with important comments. Tukey also made very many detailed technical comments. This greatly improved my understanding of statistical methods and allowed me to complete my thesis.

This was remarkable from Tukey. I discovered later that he was often many months, even years, behind in his correspondence. His office in Fine Hall had his incoming mail stacked several feet high from the floor. My package from England must have just caught his eye!

After Boyden, Feynman, DubBridge, and Pauling Tukey became, from this time, the most lasting influence of my professional life.

12.6 PhD Thesis

My chosen PhD thesis topic required novel statistical methods and substantial computing. It required use of the then new techniques for the analysis of time series based in large part on work by John Tukey. Specifically, I used the text by Blackman & Tukey: (10) which provided

the methodology that I needed.

In my case these were the time series of macro economic data. While the results of the computations produced new insight into the behavior and information content of macro economic data, the computational techniques were themselves also relatively new.

Morgenstern and Tukey joined my list after Feynman, DuBridge, and Pauling as most important and lasting influences of my professional life.

12.7 Introduction to Computing

The use of the University of London Ferranti Mercury computer made it possible to carry out the required computations. Of course, due to the time required for the computations I was required to do the computing during the late-night shift. In this I was again exceptionally lucky as I had uninterrupted use of the computer.

This also required learning programming on the University's computer. This was again a fun and valuable experience. At the time, this was an advanced computer system in both hardware and software.

Also, next door to the Mercury Center the Ferranti Atlas computer was being installed. I wandered in and talked with the installation and programming people there and thus learned about new architectural features including multiprogramming, memory protection, and paging. These techniques, commonplace now, were only introduced in the US many years after their introduction in the Manchester University systems which were provided by Ferranti.

When my thesis was in a nearly completed draft form I found that I was still unable to understand some of the computed results. While I got some advice from statisticians within the UK I was still puzzled. Therefore I sent a copy of my draft to John Tukey[2]. I knew his work and was very hopeful that he might be willing to help. Within a few weeks the draft reappeared with comments, in his usual red ballpoint pen, on nearly every page. This led to substantial work, rewriting, and more computing. But, also a very much more suitable thesis. When the thesis was ready for submission I sent final copies to Tukey and Oskar Morgenstern. They both wrote back offering me a position at Princeton. This settled my career for an extended period.

[2] John Tukey resolved a key problem.

12.8 Conclusion of Student Times

It was immensely beneficial and enjoyable to live as a student in the period of the 1950's and into the 1960's. I have interacted with many students over the years since then. Looking back on those days at no other time have such opportunities been available, and on such generous terms. This was, for me and many others, a Golden Age. How this was lost is a story that should be told and somehow taken into account.

It is at least a part of the problem that higher education now costs roughly ten times, in real terms, what it did in my time .

It is informed members who create an Informed Society which, then, is able to understand how to reason about their surroundings in a way that is fair, constructive, and beneficial.

This now still appears to be a distant goal if possible at all.

12.9 Other Activities

12.9.1 Continuing Part-time Work

On arriving in London I also found that my connections with Consolidated Engineering Corp. would be continued as they had decided to open an office near London. I spent time providing technical advice to the professional staff and worked with their customers who were mainly in the aircraft industry. I also did consulting with several UK aerospace companies, including Vickers, Westland Helicopter, Short Brothers and Harland, and Eliot Brothers. And, it was fun to be able to participate in the annual Farnborough Airshow.

These were exciting times in the development of new aircraft such as the VC10 and early plans (hopes) for Concorde. In any case, this was good diversion from my thesis work.

While mentioning the VC10 and Concorde it is worth pointing out one fact about them: for travel between LHR and JFK it was consistently quicker to fly by VC10. A main reason for this was the much better maneuverability of the VC10. Its turning radius was less than half that of Concorde. Therefore, when approaching landing an incoming VC10 even if it was behind a Concorde, was consistently scheduled for landing ahead because it could be much quicker into an available

landing slot. Also, the VC10 was quieter and much less subject to high altitude radiation. So, when having to make our usual LHR-JFK flights I always chose the VC10.

Two final items about the VC10 are fun to add:

The first flight trial quickly revealed a flaw: The study of the stability of the wings against flutter had been made using techniques that started testing for flutter at the lowest frequency for a wing assuming an engine in place to prevent the fundamental mode. It was simply forgotten that these tests made this assumption, but the VC10 had no engines on the wings. This inappropriate assumption had the following effect on the first flight trial (to which I was invited): Shortly after takeoff the wings began to flap at the fundamental mode. The pilots immediately aborted the fight sequence and came to a safe landing. The wing structure had to be modified to block the fundamental mode. This only added some minor weight and was quickly accomplished. The second flight trial went smoothly.

Second it was also discovered that the turbulence window around the tail of the fuselage had not been accurately estimated. It turned out during flight trials that the turbulence somewhat restricted the air flow through the inboard engines and the engines could not be moved further out. This was a minor efficiency loss.

In any case the VC10 was a high performance, flexible for short landings and takeoff, quiet, and reliable aircraft. It continued in service for much longer than expected.

British Airways had initially requested a new airplane which would be most effective on flights to the middle East and on to Asia. This required short runway capability. However, after the design of the VC10 was underway, BA switched their demands to Boeing and Concorde. But they also operated a limited number of VC10's. And the UK Royal Airforce also purchased a number.

For more VC10 information see Wikipedia page: Vickers VC10.

12.9.2 Shell Oil and BP

I also provided statistical and computational methods for analysis of their oceanic oil reservoir exploration data. These made use of the same programs that I had written for my thesis.

13

Princeton University

13.1 Introduction

On arrival[1]

[1] Morgenstern and Tukey welcomed me and posed many challenges both within and outside formal academic duties.

Morgenstern asked me to join his *Econometric Research Program*.

Within a few months my appointment was replaced by an appointment as an Assistant Professor in the Economics Department. I was later told that this was the first time a person just graduated with a PhD was directly appointed as Assistant Professor. Previously the initial appointments were all as Lecturers. This was however mainly luck, as most of the other Ivy League Schools had already dropped the Lecturer grade.

I also worked with Tukey in the Princeton Math department, and at Bell Labs at Murray Hill, and also later at AT&T in New York and for the rest of his life. This was an honor beyond all expectations. I only learned later that Tukey was identified as the most accomplished mathematician of his generation. He represented the US to the world concerning issues relating to mathematics and science during his entire career. This also included several extended wartime visits to Bletchly Park and GCHQ. These visits often included vonNeumann as well.

There was a University agreement arranged by Tukey, that University staff could spend some time at Bell Labs. He encouraged me to join in these visits.

For more backround see his: APS Library: Tukey entry

And, a very useful obituary by Peter McCullagh is available at: Royal Society, 07 April, 2025

13.2 Morgenstern's Research Group

Morgenstern and Tukey continued to provide exceptional opportunities to study and learn from them and also including from many others from a wide community to which they provided introductions. Prominent examples included: Kenneth Galbraith who played a key role in the War effort through the use of sound economic planning based on what was then called input–output analysis. Since he had the authority to set wages and to direct production planning he and others could cause the most efficient volume of production of materials for the War effort. This was far more effective than efforts elsewhere.

Examples of visits organized by Oskar included: General Motors Research, UCLA, Caltech, Wisconsin, and others. Immediately, Morgenstern encouraged my study of a wide range of subjects. Of course, I reread his *Theory of Games and Economic Behavior* by von Neumann(51).

He also introduced me to friends and colleagues who were interesting and challenging. I quickly discovered that whatever topic came to mind Oskar would have new and important information about it.

Subsequently I became a founding member of the Princeton Statistics Department. John Tukey, of course, was the Chairman of the new Department. Working with Morgenstern and Tukey was an experience beyond imagination. I continued to work with them as long as was possible. During this time I also worked with Tukey while at Bell Labs. We drove to and from BTL at least a day or so each week.

13.2.1 Oskar Morgenstern

Morgenstern had exceptionally wide knowledge. Important information about him is at: Morgenstern Wikipedia entry. This web site provides quite useful and accurate information. It must have been written by someone with good knowledge and having known Oskar very well.

In about 1968 Oskar established the "Econometrics Research program" which continued under other management after Oskar retired. I was a member as soon as I arrived. A good indication of the work in the ERP is the publications list at: ERP Archive.

It was a great privilege to be a close friend of his. Practically any interaction with him was a new and exciting learning experience. And, I quickly found that there were frequent invitations to meet with others,

give talks outside the University and participate in other fun and useful pursuits mainly initiated by Oskar.

He and von Neumann were also very close friends from their first meeting in Princeton. Oskar seemed to know "everyone" and to know their skills and interests. It may have been for these reasons and his outstanding intellectual ability that some members of the Princeton Economics Department were jealous and disdainful. Petty behavior is best forgotten.

Oskar also knew a great deal of European and wider history. After finding that he knew about many subjects that I hardly knew of at all I tried to find the most obscure event that I could. When I casually mentioned the subject Oskar immediately pointed out: the background for this event, while not widely known, was ...! And, he filled in important facts and consequences.

13.3 John Tukey

John Tukey (See his National Academy Entry). Even this description is not accurate. His discipline is given as Applied Mathematical Sciences. This neglects his pure mathematics, statistics, computer engineering, data analysis, cryptography and more. He was the dominant mathematician throughout his career.

An additional and excellent eulogy by Peter McCullagh is at: J. W. Tukey

John was initially taught at home until he attended Brown University graduating in Chemistry. He then entered the Princeton Mathematics Graduate program and completing his PhD in topology in three years. Each of these transitions was previously unheard of. Taken together they appear not likely to be ever attained again.

At this time the Princeton Mathematics Department was by far the most highly regarded and challenging Mathematics Department. And, its graduate program was equally challenging. It continues to maintain that reputation. The department had surely never previously considered a chemistry graduate under any condition.

John entered the Princeton graduate program in 1937, completed the M.A. degree in 1938 and completed his PhD. in 1939. Again all records for least time spent. He was then appointed as Instructor in the Mathematics Department in 1939. Another first, and in 1950 he

was appointed to Full Professor.[2] As far as records show, the youngest Professorial appointment.

[2] Full Professor in record time.

He also assumed the role of representing the US to the mathematics world. This was an official role which he held permanently.

His description on the NAS web page National Academy of Sciences mentions a few of his accomplishments, but misses many of the important ones. He made a number of trips to England during WW2 working with Turing and others, for example. (UK secrecy laws have prevented much of this from being published.)

Tukey and von Neumann both contributed to other military developments during WW2. They were visitors for extended periods at Blechly Park and at GCHQ at Cheltingham. Of course, they most prominently met with Turing on these occasions. This has been a long kept secret in the UK.

This summary helps to make clear that John was the world's leading mathematician.

13.4 Contribution to the development of the Atomic Bomb

This required numerical evaluation of the set of equations which it was hoped would correctly represent the actual bomb. Feynman was given the task of defining and numerically evaluating the bomb equations. To do this in a reasonable amount of time he needed a digital computer. However, as far as seems to be known none of the reports about the Los Alamos work mentions this key requirement.

John Tukey did not spend time at Los Alamos. However he and Feynman were close friends while they were graduate students at Princeton.

Tukey, caused IBM card-sort machines to be delivered to Los Alamos for Feymnan's use. These machines had been suitably organized by Tukey to act as (primitive) digital computers. Their use was a challenging but essential task. With these machines Feynman was able to compute the correct physical parameter values for the construction of the bomb. This took up many long nights of computations using the equipment that Tukey had provided.

The first bomb test showed that Feynman, with the equipment and skills provided by Tukey, got the actual construction right!

The fact that this key contribution has not been reported may be due to the fact that it mainly went on deep at night and using digital computers which were otherwise only known at Bletchley Park.

The exception, of course, was Alan Turing's computer which he used to break the German codes at Bletchley Park.

All of this was secret during the war and long after. However, Tukey, von Neumann and Turing were close friends and worked together during and after the war.

13.5 More key Tukey contributions

A major contribution was his participation at the meetings of the Geneva nuclear weapons disarmament conference in 1959. The conference was seriously stalled due to the fact that each side suspected that the other might claim that a nuclear explosion was really just an earthquake. Of course it was John who was asked to explain, in terms that the members could understand, that it was definitely possible to distinguish the events.[3]

[3] Explanation at Geneva Conference prevented breakdown.

The key to this problem is that earthquakes are nearly always asymmetric since they usually occur along a fault line. Whereas explosions are symmetric about the point of the explosion.

Of course, John also showed up with his usual bag of prunes.

Tukey, von Neumann, Turing and Bill Baker worked very closely together.

John also argued strongly in the determination of smoking as a causal factor for cancer. This was somewhat controversial as R. A. Fisher argued against causality. The final agreement was and is that smoking is a causal factor.

For an extended period while I was still at Princeton John and I shared the drive from Princeton to Bell Telephone Labs in Murray Hill. Typically I had spent long into the previous night computing our latest results which we then discussed during the trip.

Quite surprisingly, John never learned to program a computer. I found this amazing since he played a prominent role in the implementation of the basic circuits for the earliest machines. (This was done in part with John von Neumann).

Also, John's writing style was viewed by many as bordering on incomprehensible. The simplest understanding of this was due to John's explicit rule (and oft repeated as we wrote works together) that each sentence should be constructed to exactly express a fact or concept. Then, the next sentence should be written in the same way. No redundancy was allowed.[4] Not everyone found this easy to read. As an example, his 1959 book with Blackman, *The Measurement of Power Spectra from the Point of View of Communications Engineering* (10) has widely been a cause of severe difficulty for even well–trained readers. While this method expresses the concepts exactly, the sequence in which they are presented seems not to follow in a natural order. It has been suggested that starting at the middle of the book may be helpful! In any case, it was the first text to fully explain the subject.

[4] No redundancy allowed.

John was also a major contributor to the *Science Citation Index*.[5]

[5] Originally Published by The Institute of Scientific Information (ISI). It is now available at: Science Citation Index–Expanded

Somewhat connected with his communication skills is the, not confirmed, anecdote that when he was told a problem by a student he provided his answer with: "Your problem has a real and an imaginary part."

The most widely referenced paper that we wrote together was: C. Bingham, M. D. Godfrey, J. W. Tukey, *Modern techniques of power spectrum estimation.*(8) In this paper John wrote the first part which presented the computational Fourier methods and I wrote the complex–demodulation methods section. Note that, in all joint author works, John always insisted that the author names be shown in alphabetical order regardless of who contributed which parts.

John was also a serious ping–pong player. I do not recall ever coming close to winning a game with him.

And, John and Elizabeth enjoyed all available weekend evenings at the local square dancing hall in Princeton.

Tukey was also very much involved in intelligence work during the war. He also contributed early work on digital computers. He and von Neumann and Feynman were also close colleagues.

An additional description of Tukey's contributions is available at: Tukey Memorial by David Brillinger.

The above does not pay justice to Tukey. He was certainly one of the most skilled and accomplished mathematicians of all times.

It was an amazing privilege that he encouraged me to help with his

work.

13.5.1 Martin Wilk

Martin Wilk, at Bell labs and Princeton helped to convince me to join Bell Labs at Murray Hill where I had in any case been visiting quite regularly. This led directly to my work at AT&T. He was also of constant help in our work with Bob Breedlove at AT&T.

13.5.2 Robert Breedlove

While Martin Wilk encouraged me to join the AT&T analysis group, it was Bob Breedlove who provided definitive experience and technical knowledge of the entire Bell System and thus made the effort possible. I joined him in developing the analysis system which became the basis for the AT&T – FCC rate determination process and for all investment plans for the Company. He initiated, and with some help from me, published the description of this work in the book *An Incremental Cost Model of Message Toll Telephone Services* (11). This publication is available at: https://archive.org/details/MTSBook/mode/1up the MTS Book.

This work shows that to implment efficient economic activity it is necessary to obtain detailed data concerning the effects and costs of the required inputs and mechanisms which produce the intended results. This is termed "Input–Output Analysis" in the economic literature. But, it is hardly used in practice unless there is a crisis such as a war.

For example, this was the methodology that Kenneth Galbraith used when he was, during the war, in charge of the Office of Price Administration (OPA). See his Wikipedia entry: Galbraith OPA

And, a fun aside while in New York it happened that the intent by the AT&T New York Telephone Company to claim improvement of their services by an advertisement on their repair trucks that read “talk to us about better service”. [6]

[6] Quite soon a reply appeared painted on one of the trucks. It read ”I don’t talk to no truck”.

13.5.3 AT&T History

The history of AT&T has been documented in a number of places.

However a fair and comprehensive reporting is hard to find.

The book by Steve Coll, *The Deal of the Century*, (14) presents some of the history of AT&T's divestiture.

13.5.4 One serious oversight

Even though a prototype mobile phone was developed at Bell Labs the importance of mobile phones was not recognized by AT&T management.

13.5.5 A time to decide

And, this was a time when I more fully recognized my view: whenever I thought of an interesting and challenging problem I first looked for someone who would take it on.[7] Only if all else had failed would I consider addressing it myself. An effect of this has been that I have been little troubled by distracting publicity.

[7] Best to find someone who can likely pursue the problem.

This behavior was confirmed by a meeting that Morgenstern described to me: He and von Neumann were sitting at a Math Conference in Boulder when the young George Dantzig appeared and asked if he could describe his recent work. von Neumann listened and said "that is really important, be sure you write it up!". After Dantzig left Oskar said: "But that is the same problem that you recently explained the solution to me". von Neumann replied: of course, but he is young, enthusiastic, and he did find the solution on his own. The specific problem was, of course, the Linear Programming solution method. Dantzig, fairly, got full credit for it. See: Wikipedia:George Dantzig.

My association with Oskar Morgenstern provided great benefits and he became a life–long friend and colleague. He Immediately encouraged my study of a wide range of subjects and introduced me to friends and colleagues who were interesting and challenging. Most prominently he gave me a copy of his book *On the Accuracy of Economic Observations*, (35) This is a fundamental text for the understanding of Economic data. Very sadly, by enforcing inappropriate copyright, Princeton Press has suppressed it's availability. This despite their many times repeated refusal to print new copies. The Internet Archive has a copy moved into its "book loan" system. This is a help but since the book should be studied by every student with an interest in economic data, this is far from adequate. Princeton Press demanded the removal of the copy that I uploaded and therefore it had to be moved to the "loan" library. Unfortunately harder to read and not available for down

load from the Archive.

I quickly discovered that whatever topic came to mind Oskar would have new information about it. And, invitations for visits and talks appeared often. It became obvious that Oskar was behind all that.

13.5.6 Privileges

As a member of Morgenstern's Econometric Research Program (ERP) I was supported mainly by the Office of Naval Research (ONR) . In those, now lost, days the standard periodic review procedure was that our contact at ONR would telephone to ask about convenient days for a visit. On the agreed date he and sometimes another ONR member would appear and discuss the ongoing work with Oskar and me and also meet with our current student members and other visitors. At the end of the visit he would just say that our grant would continue as previously unless we felt that more funds were needed. The basis of their relationship was made clear by the fact that they came to us. A privilege that now seems to have been entirely lost.

However, I also learned that this was an essential procedure when I was called on to assess scientific work of others.

When Oskar was, due to University regulations, required to retire he joined the NYU Faculty in New York. A significant loss to Princeton and benefit to NYU.

13.6 A Tragic Faculty Meeting

An important early event was a Faculty meeting at which the newly proposed student loan scheme was on the agenda. I spoke, and simply said that this was obviously the dumbest idea that I had ever heard presented to an educational institution and that it should be totally rejected. I was stunned that this was not the majority view.

Much later, Princeton was the first Ivy League school to reject the use of student loans.

It will still take very many years and careers lost before recovery from the extensive damage that this imposition has caused.

13.7 The UK experience

This treatment appears to have had the most negative effect in the UK where all students must give up their rights to their bank account and have been required to gain permission to take visits outside the UK. obtain permission from the Loan Authority to leave the country, and in many cases the former student has died before completing repayment of their loan, of course, with an exceptionally high rate of interest added on.

13.7.1 The 1963 Robbins Report

Lionel Robbins, who was Head of the London School of Economics, addressed this issue appropriately.

He had been charged by the UK government to prepare a report on the eligibility to higher education in the UK. I took an interest in the preparation of the Report, and was pleased to find that the main recommendation was that:

> "Courses of higher education should be available for all those who are qualified by ability and attainment to pursue them and who wish to do so."

The above is taken exactly from the Robbins Report. The recommendation is nearly always misquoted. The Report is available at:The Robbins Report. Sadly, the UK government at the time just shelved this aspect of the Report. Returning to this principle would be as effective today as it would have been then. Failure to implement this rule causes much greater loss to society than the cost of providing the education.

It is important that the Robbins Report also specified *available* access to *higher education.* It was clear that available meant without recourse to any form of loan.

The report on wikipedia is at: Robbins Report

13.8 Princeton University Rules and Procedures

Dealing with the University's rules and customs as they were when I first arrived was another matter. I worked hard to mitigate or remove the conditions of divisiveness and exclusivity in the selection of, and

choices available to, the students, particularly undergraduates. I helped with major revisions of admissions of students on a fair basis.

Working with others we were at least partially successful in bringing about the fair admission of students, changes to the social structure of undergraduate life in order to provide fair treatment for all students, and, finally, the admission of women undergraduates. Sonia Sotomayor, as one of the first women students, has proved the value of this change. However, this was achieved at considerable cost to those of us who actively worked for the change. An alumni delegation to the President demanded my removal[8] The then President would likely have done it if he had had the authority.

[8] A useless delegation from some Alumni, all male, of course

As a member of the Statistics Department I reviewed the applicants for the PhD program. To my surprise in the stack was an application from Thomas Andrew Lehrer! (See Tom Lehrer) I naively, and in some haste, added his application to my candidate acceptance set. However, when we met, I discovered that there was opposition to him. I was unprepared for this and unable to change the decision not to accept him. A significant loss to Princeton and Statistics!

Also, during this time I became aware of IBM's role in the computer industry and their handling of computer resources at Universities. Princeton had an IBM 7094 system which, while quite primitive as compared to the London Mercury and even more so as compared to the Atlas, which replaced the Mercury.

However, it had a major advantage over most other systems, including other similar IBM systems then in use: It had a large CRT monitor display which could be controlled directly from the computer. It was surprisingly like today's PC's but much bigger and very much more expensive, of course. Even so, for someone willing to take over the machine, typically late at night, very effective interactive computing could be accomplished. A 35mm film camera was slaved to the monitor. Thus text and graphic results could be both displayed and recorded with high resolution. Results from this system appeared in most of my publications during that period.

It was Peter Warter, a professor in Engineering, who implemented the graphics software system which was also ported to other systems which had similar graphics hardware. He deserves wide recognition for this new, very useful, and easy to use software.

I was able to help with the computer operations in various ways[9], including minor repairs or corrections to software, and hardware fault diagnosis. However, one incident resulted in unexpected reactions: I

[9] Just being helpful at the University Computer Center

arrived one morning at the computer center to find that all was in chaos due to the fact that the administrator who handled the scheduling of work on the computer was out sick and their desk with all the schedules for the computer was locked. (Remember that in those days IBM computers did not schedule the work on the computer. This was done manually by the operators who followed written instructions.) I offered to unlock the desk, which I did based on my course at Caltech, and so normal working could go ahead. It was surprising to find that this caused some concern and meetings were held to discuss my "unsuitable" behavior.

After the 7094 was replaced by an IBM 370/95 it took many years before interactive and graphics capabilities reappeared at Princeton through use of other systems which were quite widely available elsewhere. During that time I made use of the systems within the Bell Labs facilities.

13.8.1 Replacement Computer at Princeton

During the discussions about the replacement of the IBM 7094 I raised the question of considering alternative suppliers. This upset IBM since they had chosen Princeton as one the Universities to which they had decided to provide 360 systems. And, they did expect that NSF would pay the full cost. This, they argued, would make the system "free" for the University. A possibly related event at that time was a visit to my office of a senior IBM executive who asked if I would like to become a consultant at the IBM Institute in New York. I asked what my duties would be. He answered that there would be no necessary duties. IBM would just pay my retainer whether I attended of not. I said that I did not accept bribes and asked him to leave immediately. This caused me to be entered on IBM's "black list". IBM seems to no longer operate in this manner, at considerable loss to them.

Subsequently I learned that IBM had, for many years, operated an intelligence unit which collected data concerning their perceived competitors. This included the current financial accounts and all interesting technical data about ongoing research and development projects. Some of this came out in the CDC vs. IBM lawsuit. It was also made evident in the case of GE's development of mainframe computers. The computer models were the GE 635 and 645. The 645 was of interest as it was one of the first US computers which supported paging. IBM obtained the GE design documents and used them to build the IBM 360/67. The evidence that the copying took place was made clear when the two

final designs were compared: they matched in detail except for one change which GE introduced very late in their development process. IBM failed to include this one minor change in the 360/67. They also obtained all such data from Sperry UNIVAC and the other computer manufacturers. From UNIVAC they copied the provably reliable design techniques which UNIVAC first provided in the 2200 Series and IBM provided in subsequent 370 systems.

Quite a few years later I gave a talk at IBM Yorktown Heights and discussed the provably correct design methods. A few members in the audience looked quite alarmed as they guessed that I knew where they got "their" design.

13.8.2 IBM's Role in Computing and Research

During this period not only did IBM play a dominant and abusive role in computing, in industry, and in research, but they also subsequently destroyed the major research labs in the US and elsewhere. Most prominently, due to the AT&T divestiture as dictated by IBM, they destroyed the AT&T research labs at Murray Hill, Holmdel and elsewhere within the Bell system.

And, of course, the GE labs were also closed. It could be that the research labs might have decayed in any case, but IBM was key to their prompt destruction.

Surprisingly IBM also convinced CBMA (Computer and Business Machines Association) to join them in attacking AT&T even though the CBMA's interests and AT&T's were closely aligned and in opposition to IBM's illegal actions.

An important view into IBM's behavior became evident in the law suit brought against them by CDC. This is reported at: Justia US Law and at: Casemine

The lawsuit was titled: "1968–1973 Control Data Corp. v. IBM"

CDC filed the antitrust lawsuit against IBM in Minnesota's federal court alleging that IBM had monopolized the market for computers in violation of section 2 of the Sherman Antitrust Act by among other things announcing products it could not deliver. A 1965 internal IBM memo by an IBM attorney noted that Control Data had publicly blamed its declining earnings on IBM, "and its frequent model and price changes. There was some sentiment that the charges were true.

In 1973 IBM settled the CDC case for about $80 million in cash and the transfer of assets including the IBM Service Bureau Corporation to CDC.

However, at about this time as part of their attack on AT&T IBM had, through a blind entity, bought one of the independent telephone companies.

13.8.3 IBM policies

One remarkable IBM policy was their annual rewards event. While nearly all organizations put on an annual event for the work force. Typically, rewards would be given to the "best" worker or at most a few best. IBM gave some reward to everyone. So, instead of most being disappointed everyone went home with some recognition.

13.9 Game Theory in Practice

I undertook to understand Game Theory due, of course, to Morgenstern. And, surprisingly, this turned out to have a prompt and practical use. I was summoned to appear for jury duty in a jurisdiction north of Princeton. I assumed that this would be quickly dealt with due to my educational background. However, due it seemed to the inexperience of the lawyers, I ended up being selected for the jury. The case was quite simple: there had been an accident at the local school. A young child had fallen and broken a tooth while running in a hall. This, his parents claimed, had serious health and emotional consequences, and the school was negligent in allowing the child to run in the hall.

The event, by the time the issue reached the court was several years in the past. For this reason there were many uncertainties including the fact that the child could not accurately remember the incident and nor could anyone else. There was disagreement on even when the event had occurred. The dentist who treated the child could also not accurately remember when or what he had done. But, the parents were adamant in their claim for major damages due to physical and emotional harm.

So, when the jury retired it seemed obvious to me that this was just an attempt to collect substantial damages with no just cause. Therefore, my objective was to cause, as promptly as possible, certainly within 1 hour, that there was no substantial fault and the case should be dismissed. In

any case, the approach to causing the jury to agree with my position was appropriately addressed through the use of n–person game theory. Thus, the first step was to establish the emerging coalitions. Three emerged through a few simple questions. The coalitions were:

1. The child was definitely seriously harmed and the school was negligent.
2. The child was not seriously harmed, but the school was negligent anyhow.
3. The child was not seriously harmed, and the school was not negligent.
4. A number of jurors who were uncertain.

Having defined the coalitions, the objective was to move the jurors to agreement that no substantial harm had been done and that the school was in any case not negligent, i.e. item 3 was the appropriate outcome.

It seemed best to address the first group first by making the argument that the "facts" were much less certain than understood by this group. They quickly became less certain and more confused and so agreed that it might be best to drop the case. That made it easy to convince them to join the no fault group. For them I pointed out that the dentist who treated the child considered the damage to be quite minor and, in fact, he had forgotten when he had treated the child. Also, the child, when questioned, could not in any detail remember when the incident occurred. In any case blaming the school would not decrease the chance of such an incident occurring again, but would likely increase the costs of the school and therefore the community would end up paying the bill. The other groups quickly joined me. That did it and the case was dismissed within the hour that I had allocated.

Harder decision cases came up over the years, but Game Theory has been a consistent and effective framework for addressing all such cases. In outline, the procedure is simple: 1) Identify the coalitions, 2) Identify the weakest coalition and 3) Identify the weakest members of each coalition.

I was also successful in helping to bring about the fair admission of students, changes to the social structure of undergraduate life in order to provide fair treatment for all students, and finally the admission of women undergraduates. Sotomayor, as one of the first women students, has proved the value of this change. This was achieved at considerable cost to those of us who actively worked for the change. An alumni

delegation to the President demanded my removal from the University and the then President would have done it if he had the power. He was subsequently replaced instead.

13.10 Surprises from Oskar

As an additional surprise Oskar was a source of a number of good stories:[10]

[10] Good stories as told by Oskar.

Another day a person was driving along a country road and noticed a farmer holding up a pig so that it could eat the corn off of a corn stock. The farmer then put that pig down and proceeded to the next one. The driver became curious and stopped and asked the farmer: "I do not want to interfere, but wouldn't it be easier and quicker if you just broke off the ears of corn and let the pigs eat them?" The farmer thought for a minute and then said: "I understand, but what's time to a pig?"

And, just one from John Tukey when a student asked for an explanation of a problem from him: Tukey replied "You have a complex problem: it has a real and an imaginary part."

Finally, a report about the fictitious Austrian thinker Dr. Alexander Zuckerkandl who claimed that the greatest problem was that of the publication an excess information. And, he wrote 3 books trying to make his important finding more widely known.

13.11 Institute for Advanced Studies(IAS) in Vienna

13.11.1 Conditions in Austria

Austria was integrated into Germany on March 13, 1938. Morgenstern mentioned that he was shocked to find that on the date of the anschluss the Austrian bureaucrats appeared in their Nazi Uniforms.

Not everyone was aware that at the end of the Second World War politicians and, more importantly the "bureaucrats" in Austria arranged that Austria would be declared to have been an "occupied country" and therefore the de–nazification program as carried out in Germany was not implemented in Austria.

It is important to understand that Austria then and now is run by key "bureaucrats", not the politicians. The politicians are elected,

hold meetings and have discussions, but the "bureaucrats" decide, and pass their authority on to favored descendants. Among the powers of the "bureaucrats" is to decide who has obtained which University degree or other examination. Thus, if someone, often female, wished to become a doctor, the required courses and studies are declared to have been completed and made official by the chosen bureaucrat and the certification as a qualified doctor is made official.

This permits individuals, mainly women, to become "qualified" doctors without any training.

During and at the end of the War Austria was fully integrated with Germany. There was no "occupation". Even well before the 1938 Anschluss many Austrians were members of the Nazi party. Sometimes this was for "convenience", such as only Nazi party members could attend the 1936 Olympics. The 1936 Summer Olympics were held in Berlin and many Austrians wanted to attend.

The Winter Olympics were held in Garmisch just across from the Austrian border.

13.11.2 Continuity of Bureaucratic Control

All government officials retained their positions. Kurt Waldheim. was a prominent example. See: Wikipedia: Kurt Waldheim.

For the Universities, again as in Germany, all Jewish faculty who had not already left were dismissed and replaced by Nazis regardless of their academic knowledge. However, after the War these appointees were not dismissed and replaced as was done in Germany. They continued for extended periods many only departing due to retirement.

And, of course, at the end of the War these politicians promptly resumed their dress as they had before the Anschluss. The effects of this behavior continue to cause problems for the proper functioning of political and educational functions in Austria.

There remains a bureaucracy which functions in secrecy but which has extensive powers. These include the issuing of University and Medical degrees. These bureaucrats pass on their positions to "suitable" successors. The corruption is endemic. This includes the fact that these bureaucrats can declare that a "student" has completed a course and is eligible for any title, such as for example, as a University Degree or a qualification as a Medical Doctor. This has led to needless deaths. This

activity is not mentioned, for example, in a Google search for "Austria officials who can grant degrees".

In any case all the doctors in the medical facilities retained their jobs despite the fact that Hitler had ordered the doctors in all psychiatric hospitals to exterminate all their patients.

One view that was expressed in Austria was that it would have been much better if Roosevelt and Hitler had joined together to defeat the Russians.

This history helps to explain the fact that Vienna and Baden bei Wien have become popular homes for "suitable" Russian oligarchs.

However, there are many who have worked against these historical practices. Time will tell if substantial progress can be achieved. In any case it is to be hoped that my efforts to improve education in economics, statistics and more open and informed practices may have had some useful effects.

13.12 Institute for Advanced Studies(IAS) in Vienna

Another part of my work came about through Oskar Morgenstern. He and Paul Lazarsfeld arranged through the Ford Foundation to provide substantial funds for a new Institute in Vienna, the *Institute for Advanced Studies in the Social Sciences*. A review of the Institute is available at:
Institute for Advanced Studies(IAS) Vienna

Oskar had asked me to spend substantial time at the Institute in Vienna to teach statistics and economics and to help in ensuring the better management of the Institute.

The purpose of the Institute was to counteract the current state of higher education in Austria. Since Oskar knew my background of life in Germany he proposed that I spend time lecturing at the Institute. This was a fun and, I hope, constructive experience. The Institute also had an IBM computer model 1620 donated by IBM. This was the first educational computer installed in Austria. I helped in its installation, training the support staff and lecturing on computational methods for the Social Sciences.

Through Morgenstern IBM had previously offered a computer (model 7090) to the University. But, the University refused the offer on the ground that they would have to employ a technician to operate it.

I believe that the Institute achieved a substantial improvement in higher education in Austria and reduced the Nazi influence.

13.12.1 Surprises on Arrival at the Institute

When I arrived at the Institute I found that there were many rules.

For example, after a few lectures I realized that I was late for the current lecture. When I arrived at the lecture room I found that all the students were standing in the hall. I asked: is the door locked? But, the answer was that there was a rule that the students could not enter the room until the Professor had arrived! So, I entered the room and waited until about half of the students had entered and then I walked out. This led to serious confusion as there was no rule for this case. So, I walked back in and pointed out the stupidity of the rule and said if this happens again I am not coming back. From then on the lectures ran pretty smoothly, even though some of the Professors did not quite get it.

There were more substantive rules such as during seminars no one was allowed to criticize the professor who was speaking. Since many of the "Professors" were not too well informed, a case of a wrong assertion came up quite quickly. I pointed out the error and said "we all make mistakes" even though this one is particularly obvious. This led to consternation, of course. But, the students got the idea.

In any case, the Institute prospered and quite a few of the students found positions in Austrian Universities. So, the main objective was accomplished. The Institute still operates at a new location but it now plays a more normal, if not traditional, role. See Institute for Advanced Studies, Vienna

13.13 An unexpected event

On one of the trips returning to Princeton from Vienna in 1971 I went to the Vienna airport to board a fairly early DC–9 flight on SwissAir to JFK connecting through Zurich. I checked in but noticed that visibility was very low and so expected a cancellation. However, the flight was called for boarding. Opting out was a possible choice but I was also pressed for time, so I boarded with a load of 76 passengers. Takeoff appeared normal until close to takeoff velocity and required engine rotational speed (V&R). At this point there was a loud impact and the

pilots hit full emergency abort. The plane came to a stop after the front under surfaces had slid along the runway for an extended distance and started to burn. The aircraft had in fact collided with a Cessna Twin with four passengers on board. The traffic controllers wroongly believed that the Cessna had taken off. Of course all passengers in the Cessna were killed and only minor remnants of their bodies could be recovered.

However, as the DC–9 slid to a stop it was rapidly burning from the front under surfaces and smoke was filling the cabin. The stewardesses seemed confused, one asked about serving coffee! I immediately activated the front emergency door and demanded that passengers immediately hit the slide. Any hesitation resulted in a full push out. I was the last to leave, but on the way running from the burning aircraft I noticed a passenger trying to light a cigarette. He was flattened to the ground but got the idea that it was time to run. There was, of course, an immanent danger of fuel ignition.

The Vienna airport authorities managed to control the news and nature of the failure of correct procedures. They got away essentially with an "accidental mishap" as reported in the Vienna press. I left the scene immediately and without detection and found a telephone to make contact with friends who would be concerned.

The flight was on St. Stephan's Day which likely contributed to the attempt to make the flight despite unacceptable weather. Visibility was much below accepted limits. The flight the next day was normal, but I was a day late back in Princeton.

13.14 Asides from this time

An event from the good times of Kennedy's 1960 election campaign was, as quoted from Galbraith's Letters (pg. 168) (24) went as follows: Galbraith was in a small town in the South when the Kennedy–Nixon debate took place. He listened to the debate while in a small barber shop. At the end of the debate he asked the proprietor how he liked it. The barber answered: "So help me God, ah'm digging up two from the graveyard for that boy." Galbraith added in his message to Kennedy: "I was glad to see religion coming constructively into the campaign."

13.15 Ilse

We met when I was teaching at the Institute for Advanced Studies in Vienna. And we came together in London when I moved to Imperial College in 1969. We have been together ever since. She was also a top skier in her school and we have had many happy days following Émile Allais' advice in Austria, Oregon and, of course, Mad River Glen, Vermont.

Our time in London was exceptional. And, as will be further described, continued to the present with periods in the United States, on both the East and West Coasts, and back in London.

14

Computer Inquiry II

A fundamental change took place due to the *Computer Inquiry II* which was an IBM driven, but FCC carried out antitrust review. IBM's objective was to remove AT&T as a potential competitor and, if possible, to take over communications businesses including telephone services from AT&T.

This inquiry was initiated by the FCC as *The Second Computer Inquiry*, also known as Computer Inquiry II, with a Notice of Inquiry and Proposed Rulemaking on August 9, 1976.

The final result was that AT&T President Charlie Brown entered into the agreement to divest the Company into Regional independent units. This closed all of the AT&T facilities and assigned them to other entities. These were typically local AT&T branches. The integrity of the AT&T System was lost. It is now widely recognized that telephone and message toll traffic facilities are now much inferior than before.

IBM, who had sponsored this, thought that they would benefit, but this failed to materialize. IBM did not it appears achieve any of their objectives.

14.1 Closure of Research Labs

And, as a side effect, this caused the closure of the main corporate research facilities in the US and also elsewhere. The former AT&T research labs at Murray Hill, Holmdel and elsewhere were all closed. And, other companies such as GE closed their labs. Various forms of research continue at Universities and agencies such as NASA, but the loss of the industrial labs has had very serious negative effects. In addition, the separate telephone companies which were created have

proven to be higher cost and much lower quality of service than what AT&T had provided before.

14.2 Final Cause and Result

AT&T had a long-standing contact with IBM at the board level which took the form of regular meetings of the the two boards. These were held at remote locations in Connecticut under strict secrecy. It was AT&T's understanding that both sides were being frank. That appears to have been initially the case, but IBM changed to include these meetings in their effort to destroy AT&T. They chose this due the impression that AT&T would increasingly dominate communications and as a result would increasingly use computers to provide communications and other services.

It was on the day after the Consent Decree was entered into that Charlie Brown realized his error in trusting IBM. He came to me and simply said that he wished that he had taken my advice.

15

Imperial College

In 1969 I joined the Math Department at Imperial College, London. My title was Reader in Statistics which was an honor and gave me full opportunity to pursue research.

One interesting event was when I gave a series of lectures to students being educated to become specialist doctors at Middlesex Hospital. London.

This involved convincing them that there could be uncertainty in patient data that had been measured and recorded. I quoted from Mike Healy's study of blood sample results. (See: See Michael Healy's Wikipedia page) A key result reported in his publication was that it quite often happened that sending the same sample twice to the same lab produced two quite different results. There was evidence that this publication led to some improvements in the test lab quality control procedures. It would be interesting to study how well this works today.

15.1 The Royal Statistical Society

While at Imperial I was asked to join the Royal Statistical Society. This seemed appropriate, but I discovered that a condition of membership was that every member when asked had to give the "best statistical advice". I pointed out that it was often not known what would be the best advice. Therefore, I could not join.

However, Babbage with Thomas Robert Malthus and Richard Jones were founders of the Society so they had a solid start and I should have been more tolerant!.

15.2 Continuing work at AT&T

This was facilitated in very substantial part though use of the international telephone connection between London and New York. This was the usual connection for voice traffic. But, it worked normally for dialup computer access. [1]

[1] International dialup computing was convenient.

An amusing aspect of this was that initially, when working at home in London, it was necessary to go through the BT International operators. I would give the operator the US phone number for the New York AT&T computer modems. But, I would also, until they all got to know me, explain clearly that I really wanted the high–pitched noise that the modem emitted on connection. Sometimes they would still say: very sorry sir, I will dial the number again. In any case there were only a few international operators and we got to be friends.

In addition, we spent the Summers in New York while I worked directly at the AT&T Corporate Headquarters in New York, continuing the modeling work. This was all agreed with Imperial who seemed to find it useful that I continued contacts with Bell labs and AT&T.

Subsequently, AT&T arranged for direct dialing between London and New York. Then it was important to use the correct prefix code which forced routing of the call through a cable instead a satellite link. This was due to the long transit time for the satellite path. At this time it became obvious that the satellite path was also not fully effective for voice and most voice traffic was and is now routed through cable.

In addition, we spent the Summers in New York while I worked directly at the AT&T Corporate Headquarters in New York, continuing the modeling work. This was all agreed with Imperial who found it useful that I continued contacts with Bell labs and AT&T.

15.3 BT accounting

An administrative problem when using the phone for connection to the computer in New York was that BT only provided bills on a three month cycle. AT&T wanted to reimburse me on a monthly basis even though BT insisted on charging on the three month basis.

However, this had an additional problem: The mechanism BT used to account for phone usage was a meter which accumulated the number of units used during each 3 month period. Of course the meter had a

fixed maximum reading after which the meter readout rolled over to all zeros. BT determined that there had been a rollover if the new reading was less than the previous reading. Unfortunately the extent of my usage had the effect that the meter quite often rolled over more than once within the reading period. So, there were three month periods when my bill was very low even though my time used while logged in was high.

AT&T became concerned about this but nothing seemed to be possible to conveniently resolve the problem.

However, I also mentioned that if direct dialing were installed between London and New York at least the operator handling would no longer be needed. So, AT&T implemented Direct Distance Dialing (DDD) between New York and London. This was much more convenient, but the billing problem was never solved.

It helped that the communications interface for the UNIVAC 1106 was configured so that it was easy to re–connect to a session that was active when the line dropped. Just redialing allowed reconnection without loss of information. This was a standard UNIVAC feature in those days when phone connections, particularly international calls, did in any case occasionally drop.

And, the time that a user was logged in was recorded in the computer logs so it was easy to keep track of the actual time spent.

At the beginning of this mode of working I happened to meet with a senior member of the BT Research Center at Dollis Hill (this was the location of the BT research facility which also helped build the computer for Bletchley Park.) He assured me that international dialing to a remote computer was technically impossible.[2]

[2] Why would he think this? I just said "thanks" and dialed-in as usual.

15.4 New applications of Statistics in Cartography

I first met David Bickmore in about 1972. He came to see me about computing and data problems. He was working on the digital representation of spatial data for the production of digital maps. He had a PDP11 quite near the College which included peripherals for plotting high–resolution maps. He was on the faculty of the Royal College of Art. And, his computer was housed nearby.

It was fun to help with this and it gave rise to a useful story. It had been noticed that the DEC system occasionally failed for no identifiable

reason. After rebooting it again ran normally. After several of these incidents the DEC repair person was called to try to find the problem. He ran the standard diagnostics without error. However, one of the staff said "but these errors just occur without any prior indication of an error". The DEC repair person replied "I have never seen an undetected error on DEC equipment." Finally, the problem was solved by replacing major components until the problem went away.

Subsequently, UNIVAC and later IBM (copying the UNIVAC implementation) adopted comprehensive error management. But other suppliers seem not to have done so.

And Bill Gates has insisted that no error detection could be implemented in computers running Microsoft software. He specifically went to Intel and told them that they could not supply memory chips which contained any error detection. If they chose otherwise he would cancel all their Windows licenses.

On PCs hardware errors appear to be fairly rare. However, no error detection is implemented so they appear to be correct even though errors have occurred, or they just fail completely (In Microsoft terms, the "black screen" event. [3] For a detailed study of undetected errors see (4) and (5). These appear to be the only substantial studies of computer failures due to undetected errors.

[3] It is odd that no one seems to take much interest in errors in computer systems. Of course Gates and Microsoft are opposed to any error checking: this just costs money and makes them look bad. They prefer wrong answers or system failures, particularly in hospitals of course.

We very much preferred lunch at the RCA rather than Imperial! In fact, lunch in the Faculty dining room at the top of the RCA building was a most enjoyable event. The plates and cutlery were creations of artists at the Royal Collage, and the food and company were a great attraction.

During an earlier period David was Head of the Cartographic Department of Oxford University Press. He gave talks and did much to establish sound methods for geophysical data collection and analysis. He wrote an important book *Automated Cartography and Planning*(7). He published widely and many of his research papers appeared in *The Cartographic Journal*. (The Cartographic Journal). And, he and his wife Alison were close friends for many years.

15.5 Fun while Traveling

As we were standing in line at UK Immigration at Heathrow we noticed that Alan Bennett was just ahead of us. When his turn came to be asked: "Are you here for business or pleasure?" He answered: "What do you

call a funeral?" The Immigration official allowed him through without a smile.

15.6 Our Friends in London

An important aspect of this time in London was the opportunity to meet dear friends.

15.6.1 Arthur & Cynthia Koestler

Shortly after we moved to London we were offered the opportunity to live in a flat at the home of Arthur and Cynthia Koestler at 8 Montpelier Square. This was made especially enjoyable when we got to know the Koestlers and were able to enjoy their company.

Arthur was an amazing person as well as an excellent author. His book *Stranger on the Square*(29) is a most enjoyable portrayal of his life when he and Cynthia lived on the Square. We became close friends and I was able to help with statistical questions. And, I became Arthur's "librarian" since Imperial College declined to allow him access to its Library. I checked out whatever material he needed.

15.6.2 Stan Kelly–Bootle

And, at about the same time, we met Stan Kelly–Bootle. He became a lifelong friend. His knowledge of mathematics, computing, all forms of music and spectacular entertainments provided great enjoyment while in London and continuing when he preceded us to California.

Our actual meeting was a surprise. He came to my office in Imperial College as the Universities representative for Sperry Univac and he was interested to know if there would be any interest in the College purchasing a UNIVaC computer system. I had to tell him that there would be none. The physics folks just wanted a CDC system like their rivals in the US. Anyhow there was no money available.

That evening at home we turned on the TV for the news and there was Stan Bootle the UNIVAC sales person, being interviewed as Stan Kelly–Bootle, an expert on English football and particularly knowledgable about the Leeds and Liverpool teams.

He also told the story of the Liverpool football fan announcing to his wife that he he was off to the Liverpool–Leads match. She complained "you love Liverpool more than you love me". He answered "no, I love Leeds more than I love you!"

Stan obtained a first in mathematics at Cambridge, worked in computing, was President of the UK Porsche Club, constant attendee at Bayreuth, author of articles in the CACM Journal, close friend and sometimes manager of Stéphane Grappelli and the Jazz Club of France members, author of one of Cilla Black's popular songs, and much, much more.

Stan also knew Django Reinhardt who was the guitarist in the Jazz Club. However, Reinhardt was an illiterate gypsy. So, when he first was offered a contract to perform in the UK he was advised that he should not just accept the contract, but must point out a condition to which he objected. Unfortunately, he pointed to the paragraph which stated that he would be reimbursed for all travel expenses.

And, early from when we met him, Stan invited us to come along to hear Stéphane Grappelli play for the the North London Polytechnic Student Jazz Club. Grappelli played spectacularly to the audience of about 20 students and obviously enjoyed himself. Later we heard him play at Carnegie Hall. Much less fun and thrills in the "formal" environment. We also met and heard him in the Village, and, with Stan, in San Francisco.

Stan also often picked us up for an evening at Ronnie Scott's. Ronnie was a good friend of his so we were well–treated. One incident was especially fun: Ilse and I were dancing on the small dance floor when Ronnie came on to make some announcement. He made a comment about our dancing. I answered: "You stick to the announcing and we will take care of the dancing." This brought a great round of applause!

Examples of his skills and interests are at: Stan Kelly–Bootle Sings....

During this time, we moved from the Koestlers to 4 Melbury Road in Holland Park. This was our permanent home for extended periods until we moved to Stanford in 1989.

15.6.3 Carlos & Sheila Sancha

The Sanchas were our neighbors in Melbury Road and became very close friends. Both were exceptional. Carlos was a portrait painter

who painted many of the UK Royalty and distinguished figures from throughout the world. He and Ilse shared interests and skills in painting and I shared with him fun stories from his participation as a trainer of UK fighter pilots during WW2 and other surprising persuits.

Sheila wrote delightful children's books mainly centered on English medieval history. Examples of her work include: *Knight after Knight* (42) and *Lincoln Castle: The Medieval Story*(43).

15.7 Information Sciences in the UK

There were several centers developing computer technology and systems.

15.7.1 University of Manchester

The modern digital computer was invented by a number of people. In the UK one of the most prominent was Alan Turing. He had been at Bleachley Park and he designed and help build the computer there. John Tukey also participated in this work and at GCHQ. After the war Turing took a job at the National Physical Laboratory. However, this did not go well as, due to the secrecy laws still in effect, he could not admit to them that he knew anything about designing or building a computer. Therefore, he had little support.

This, fortunately, led to his move to Manchester to join with Fred Williams, and Tom Kilburn.

Key aspects of programming were developed at Manchester by Turing, Tony Brooker and Derrick Morris. Derrick occasionally mentioned that he learned programming from Turing. He was lucky, and exceptionally skilled.

During the mid to late 1960's Information Sciences in the UK[4] were developing rapidly and most specifically at Manchester University which was by far the world's leading contributor. They developed and implemented the Mercury (mid–1950's) and Atlas in the early–1960's.

[4] A sad tale of failure of any sense of value at Governmental level. Nothing learned from Babbage or his followers.

The production versions were planned to be built and sold by Ferranti. However, Ferranti took little interest in commercial development.

A key new construct introduced in the Atlas was "paged memory". (This is the technique of mapping a series of equal-sized "pages" so that

they appear to any program as a single block of memory of the size requested by the user program.)

Unfortunately there was no support for this work at any governmental level and Ferranti closed its computer business. However, See below at 15.9.

15.8 IBM Interest in Computer Technology

An example of the nature of the Manchester University work was an incident initiated by IBM at their headquarters. After long delay the senior management at IBM became aware of the role of a computer technology termed "paging" which was one of the key inventions at Manchester. The IBM president, Thomas Watson Jr., requested that Manchester University send a qualified person in order negotiate patent rights for IBM. The person chosen was Tom Kilburn, one of the inventors of paging. While he was at Yorktown Heights, New York, Kilburn was summoned to Watson's office. Watson stated that he understood that IBM had to license this technology from Manchester University, but he went on to say that he had thousands of research staff within IBM who do not seem to produce anything. However, he heard that at Manchester there was a group of only about 5 people. So he asked how can it be that with so few people we have to obtain licenses from you?

Kilburn replied while pointing at the "THINK" sign on Watson's desk: "At Manchester we do not waste time with that kind of thing, we get on with the job." IBM obtained the licenses, but Manchester received practically no benefit from IBM nor from the UK government which had determined that nothing of value was being produced at Manchester.

The chairman of ICL, which was last remaining UK computing company, testified to Parliament that Manchester had provided nothing for them. This despite the fact that the prototypes for all their computers had been designed and constructed at Manchester.

However, it was clear at this time that IBM intended to dominate computing and information processing and destroy any organization that impeded this goal. This is a main reason why they, in secrecy, attacked and finally destroyed AT&T.

15.9 An effort to enable better computing systems

At this time a friend, Norman Sanders, (See INRIA.hal.science), who then had responsibilities for engineering computing at Boeing, arranged with a total of 20 colleagues to purchase 20 Atlas computer systems from Ferranti. The Ferranti Atlas was based on the latest Manchester system design and implementation.

He and most of his colleagues had been using IBM 7094 computers but were being required by IBM to replace these with IBM 360 Models. These seemed not well–suited to the engineering work that was needed. Therefore, he went to Basil de Ferranti and made the offer of purchase of 20 systems to be delivered to the US. He had one specific request: Ferranti would have to provide technical support based in the US. Basil de Ferranti replied: "You can always reach us here in Manchester".

No deal was completed. And, in the end only 5 Atlases were built and delivered to UK Universities and research facilities. They provided an exceptionally high quality of computing resources for an extended period. A not too accurate description of the Atlas development and use is at: https://en.wikipedia.org/wiki/Atlas_(computer)

15.10 Computing at Manchester

Manchester University has some records of the Department in their Archive at: Computing Records

15.11 The close of the computing industry in the UK

However by 1983 the computing industry in the UK had gone into sharp decline. I, sadly, had to mediate that. I was commissioned by the ICL Chairman Rob Wilmot to provide a report describing what would have to be done to enable a viable UK computer industry based on ICL. Charles Smith and I wrote the report, but Rob Wilmot simply said "I cannot do that."

This resulted in ICL was bought by Fujitsu and then was closed down. That ended any major UK participation in provision of computer systems.

A key point in the report to Wilmot was that the current ICL software

was seriously ineffective. ICL had chosen to adopt the Manchester hardware design, but not the Manchester software.

The Manchester University software was by far the best designed and implemented since then and still effective now. Univac made use of it for some of its products and modified their main systems to be significantly closer to the MUSS design. In addition, both systems used a Flowcode representation in order to make the code easier to understand and maintain. ("Flowcode" is a generic term for diagrammatic representation of the flow of program execution.)

The ICL attempt to write their own software was fatally flawed. Customers consistently refused to upgrade the software due to errors and incompatibilities in each new version. The errors they knew were less harmful than the problems in the new software.

15.12 A concern about British Telecom (Now named BT Group)

It was during this time that I learned a quite alarming fact about BT. They had been very late in converting their telephone switching centers from the mechanical stepper switches to the newer ESS (Electronic Switching System) type switches. Various attempts had been made, but they proved not successful.

Therefore the BT chairman finally contracted with a US engineering company to develop a suitable switch. I happened to know the Company and so learned more about the conversion. This was carried out and the Company participated in commissioning the first few centers. This gave rise to a surprising fact. Many of the connections had been miss–wired so that customers were paying someone else's bill. One estimate by the contractors was that about 20 percent of the connections were incorrect.

However, prior to the switch over BT declared that there were no errors. And, if an individual or poor family which hardly used their phone found that they received a very large bill (in fact for someone else's usage) BT declared that the bill was correct and if they did not pay up their phone would be disconnected, This did in fact happen on quite a number of occasions.

This of course caused substantial harm, distress, and even loss of life for elderly people living in more isolated homes.

AT&T was astounded to learn this.

To this day BT restricts, through their ownership of all of the telephone wire, the implementation of more modern communications particularly for internet services. Thus, no matter what speeds BT advertises the last wire to the customer premises is BT phone wire. This provides, using ADSL modems, at best using ADSL2+, up to 24Mbps).

Slowly, other fiber service providers are using fiber to the premises, but this requires permissions and digging up channels along each street.

16

Systems Development Foundation

As a staff member of the Corporate Advisory Board of the *Systems Development Foundation* (SDF) from 1982 through 1992 I provided reviews of research projects for SDF funding. The key person I worked with was Charles Smith who had been at Princeton and was a long time and close friend of John Tukey. Charles and I did much of the work of finding suitable individuals or groups for SDF funding. John Tukey joined the review of a number of the more interesting projects. The challenge was to allocate about $300 million as soon as possible. This was made more challenging when we found at the end of the first year, due to reasonable investments of the unallocated funds, we had more available funds than we started with!

Others at SDF included the Chairman Arnold Beckman, Edwin Huddleson, and Carl York. I got to know Ed Huddleson quite well and he mentioned that one of his tasks was to act as the lead attorney for IBM dealing with the West Coast and Asia. This task included dealing with the fact that Asian computer manufacturers were manufacturing and selling cloned IBM 360 model computers. This was clearly against US law. However, direct attempts to restrain this practice had failed. So, Ed organized FBI agents to act as persons who could supply advance information about IBM computers for a suitable fee. This was made known to the Japanese manufacturers who were requested to come to a meeting in San Jose where they could receive the new design documents. When they arrived they were arrested and jailed by the FBI. This got the appropriate attention from the affected manufacturers in Japan. His obituary in the New York Times is at: Ed Huddleson.

16.1 Frequent visits to Munich and Austria

During this period we made visits in order to see my father in Munich and Ilse's family in Austria. In those days it was quite easy to drive, usually stopping off for a night along the way. These were good times! My father was still revered in Munich and we joined him at many events. Since he wore his "Bayerisches Erhend Kreutz" (a lapel pin indicating the award to a highly valued person in Bavaria) we were more than welcomed to all the Museums, Galleries and Castles.

Of course in the Winter months the trips included extended periods of skiing.

17

Perspectives on Science

While important discoveries were made, particularly in China, from quite ancient times the rate and importance of discovery accelerated in the Western world most prominently due to Huyghens. He completed his discovery of the nature of light in 1678. But he only communicated the results more widely in 1690.

17.1 Coherence

Christian Huyghens first discovered that light in free space is transmitted without any change in the properties of the light. This is termed that light in free space is *perfectly coherent.*

His results are available on the Internet Archive in the original french at: Huyghens, *Traité De La Lumière* and in English translation at Huyghens, *Traité De La Lumière (English translation)*.

The key discovery was based on the observation that light arriving at the earth had the same intensity regardless of how far away the light had originated. While seemingly simple, this observation required careful thought and measurement. It is fundamental to the understanding of the nature of light.

17.2 Introduction to Huygens Treatise on Coherence

Huygens' Treatise reported the coherent nature of light in free space.

The Preface in English translation is reproduced here:

Translator: SILVANUS P. THOMPSON.

PREFACE

I WROTE this Treatise during my sojourn in France twelve years ago, and I communicated it in the year 1678 to the learned persons who then composed the Royal Academy of Science, to the membership of which the King had done me the honour of calling me. Several of that body who are still alive will remember having been present when I read it, and above the rest those amongst them who applied themselves particularly to the study of Mathematics; of whom I cannot cite more than the celebrated gentlemen Cassini, Römer, and De la Hire. And although I have since corrected and changed some parts, the copies which I had made of it at that time may serve for proof that I have yet added nothing to it save some conjectures touching the formation of Iceland Crystal, and a novel observation on the refraction of Rock Crystal. I have desired to relate these particulars to make known how long I have meditated the things which now I publish, and not for the purpose of detracting from the merit of those who, without having seen anything that I have written, may be found to have treated of like matters: as has in fact occurred to two eminent Geometricians, Messieurs Newton and Leibnitz, with respect to the Problem of the figure of glasses for collecting rays when one of the surfaces is given.

One may ask why I have so long delayed to bring this work to the light. The reason is that I wrote it rather carelessly in the Language in which it appears, with the intention of translating it into Latin, so doing in order to obtain greater attention to the thing. After which I proposed to myself to give it out along with another Treatise on Dioptrics, in which I explain the effects of Telescopes and those things which belong more to that Science. But the pleasure of novelty being past, I have put off from time to time the execution of this design, and I know not when I shall ever come to an end if it, being often turned aside either by business or by some new study. Considering which I have finally judged that it was better worth while to publish this writing, such as it is, than to let it run the risk, by waiting longer, of remaining lost.

There will be seen in it demonstrations of those kinds which do not produce as great a certitude as those of Geometry, and which even differ much therefrom, since whereas the Geometers prove their Propositions by fixed and incontestable Principles, here the Principles are verified by

the conclusions to be drawn from them; the nature of these things not allowing of this being done otherwise. It is always possible to attain thereby to a degree of probability which very often is scarcely less than complete proof. To wit, when things which have been demonstrated by the Principles that have been assumed correspond perfectly to the phenomena which experiment has brought under observation; especially when there are a great number of them, and further, principally, when one can imagine and foresee new phenomena which ought to follow from the hypotheses which one employs, and when one finds that therein the fact corresponds to our prevision. But if all these proofs of probability are met with in that which I propose to discuss, as it seems to me they are, this ought to be a very strong confirmation of the success of my inquiry; and it must be ill if the facts are not pretty much as [represent them. I would believe then that those who love to know the Causes of things and who are able to admire the marvels of Light, will find some satisfaction in these various speculations regarding it, and in the new explanation of its famous property which is the main foundation of the construction of our eyes and of those great inventions which extend so vastly the use of them. I hope also that there will be some who by following these beginnings will penetrate much further into this question than I have been able to do, since the subject must be far from being exhausted. This appears from the passages which I have indicated where I leave certain difficulties without having resolved them, and still more from matters which I have not touched at all, such as Luminous Bodies of several sorts, and all that concerns Colours; in which no one until now can boast of having succeeded. Finally, there remains much more to be investigated touching the nature of Light which I do not pretend to have disclosed, and I shall owe much in return to him who shall be able to supplement that which is here lacking to me in knowledge. The Hague. The 8 January 1690.

NOTE BY THE TRANSLATOR

Considering the great influence which this Treatise has exercised in the development of the Science of Optics, it seems strange that two centuries should have passed before an English edition of the work appeared. Perhaps the circumstance is due to the mistaken zeal with which formerly everything that conflicted with the cherished ideas of Newton was denounced by his followers. The Treatise on Light of Huygens has, however, withstood the test of time: and even now the exquisite skill with which he applied his conception of the propagation of waves of light to unravel the intricacies of the phenomena of the double refraction of crystals, and of the refraction of the atmosphere,

will excite the admiration of the student of Optics. It is true that his wave theory was far from the complete doctrine as subsequently developed by Thomas Young and Augustin Fresnel, and belonged rather to geometrical than to physical Optics. If Huygens had no conception of transverse vibrations, of the principle of interference, or of the existence of the ordered sequence of waves in trains, he nevertheless attained to a remarkably clear understanding of the principles of wave-propagation; and his exposition of the subject marks an epoch in the treatment of Optical problems. It has been needful in preparing this translation to exercise care lest one should import into the author's text ideas of subsequent date, by using words that have come to imply modern conceptions. Hence the adoption of as literal a rendering as possible. A few of the author's terms need explanation, He uses the word "refraction," for example, both for the phenomenon or process usually so denoted, and for the result of that process: thus the refracted ray he habitually terms "the refraction" of the incident ray. When a wave-front, or, as he terms it, a "wave," has passed from some initial position to a subsequent one, he terms the wave-front in its subsequent position "the continuation" of the wave. He also speaks of the envelope of a set of elementary waves, formed by coalescence of those elementary wave-fronts, as "the termination" of the wave; and the elementary wave-fronts he terms "particular" waves. Owing to the circumstance that the French word *rayon* possesses the double signification of ray of light and radius of a circle, he avoids its use in the latter sense and speaks always of the semidiameter, not of the radius. His speculations as to the ether, his suggestive views of the structure of crystalline bodies, and his explanation of opacity, slight as they are, will possibly surprise the reader by their seeming modernness, And none can read his investigation of the phenomena found in Iceland spar without marveling at his insight and sagacity.

S. P. T.

June, 1912.

17.3 Information Contained in Photons

Poynting explained the properties of light in his paper *The Wave Motion of a Revolving Shaft, and a Suggestion as to the Angular Momentum in a Beam of Circularly Polarized Light* (39). This paper is also available at: archive.org. It points out that photons have a large number of degrees of freedom due the orbital angular momentum states. Thus a

single photon can contain and transmit an indefinite number of bits of information.

This is in conflict with what has been the established view as, for example, expressed by Denis Gabor that photons have only 2 states and therefore can only hold one bit of information. See his paper which is available at: Communication Theory and Physics, Trans. IRE Professional Group on Information Theory, vol.1 no. 1, 1953) (20).

More about this is also available in my library on the Internet Archive at the paper: Noise and Information.

18

Time in Pennsylvania

Since the period at AT&T was completed we moved to Pennsylvania where I took on a role at Sperry UNIVAC. My role was to advise the President and others on issues that could help in the Company's performance. I also took on the role of Director of Research since this function had fallen into a dysfunctional state.

18.1 Michael Gottlieb

During this time I often spent time at Caltech and Ilse often came with me spending long periods in the art museums.

We met Michael there quite by accident but quickly discovered that he was one of a very few people who had extreme skills in several areas. Most prominently he is an exceptional mathematician. But also, an expert programmer including WEB programming.

A major effort that he has undertaken is the Feynman web site at: feynmanlectures.caltech.edu This site demonstrates both his mathematics and physics skills in correcting many typos in the lectures. Feynman was well-known for typos! And Michael's WEB programming skills are demonstrated in his making the lectures easy to read and manage on the WEB.

This site has become the principal site for the study of physics as taught by Feynman. It is also the definitive site for the Lectures since it provides corrections provided mainly by Michael.

18.2 An Opportunity for Ilse

During this period Ilse completed her art studies at the Pennsylvania Academy of the Fine Arts in Philadelphia, Pennsylvania Academy (PAFA) graduating in 1981. She has painted a number of commissions and has had paintings accepted for the London Royal Academy Summer Shows and, of course, at exhibitions at the Chelsea Arts Club where she is a member.

Her knowledge of the works of the classical painters is exceptional. In this she lives in an earlier, maybe even happier, age.

In addition she can identify the painter of a painting quite exactly. We were viewing an upcoming sale of old masters at Sothebys in London when Ilse looked at a painting labeled as a Rembrandt. She immediately said "That is not a Rembrandt." A Sotheby's staff member happened to overhear this. When we returned on the next day the painting had been removed. [1]

[1] From Eileen Agar: A picture in a museum perhaps hears more silly remarks than anything else in the world, so we should comport ourselves with the masterpieces of art as with exalted personages – stand quietly before them and wait for them to speak to us.

18.2.1 Ilse painting

On the advice of Arthur De Costa (See `https://www.pafa.org/museum/collection-artist/arthur-de-costa`). Ilse undertook, as a training method, the copying of major paintings. She made copies at the *Philadelphia Art Museum*, at the *Kunsthistorisches Museum* in Vienna, and at the *Legion of Honor in San Francisco*.

During this time I often accompanied Ilse to Art Museums where she was copying paintings by painters whom she admired, particularly Turner and Rembrandt.

While accompanying Ilse[2] I spent some time studying the techniques used by other copyists. These other copyists were surely producing the copies as a profession.

[2] A mystery concerning Ilse's painting in Art Museums

However, something was remarkable: The copyists essentially employed a "copy small squares" procedure. They observed each small square in the original and tried to exactly reproduce the square in the right position on their canvas. Typically they stepped along painting each adjacent square along a full row across the painting. It was easy to match up any square on the original at its position on the copy. The two squares looked nearly identical. However, when looking at the overall painting, the copy seemed obviously different from the original and definitely not as good. Nor in any case convincingly of high quality.

When I observed Ilse's work in progress there was something fundamentally different. She spends considerable time studying the original and only then starts her painting. She paints over quite wide areas. As she did more work her copy more and more clearly resembled the original. I tried to "match up squares". This proved impossible. There were no squares that matched! However, when her painting was completed to her satisfaction, the two paintings appeared to be identical.

Often observers, particularly children, would comment "why are you making two copies?"

Despite trying to understand "how this works", I have not succeeded at all. I have asked others, including people who work on imaging, but they have not offered an explanation. This appears to be an important unsolved problem in image understanding.

Here is are examples of Ilse's work:

William Turner: The Burning of the Houses of Parliament

The Masked Ball

Looking at You

18.3 Skiing again

Of course this period also provided good skiing opportunities. There was skiing close enough for day visits and Mad River was close enough for a day trip if starting early enough or also easily staying overnight.

During this period we stayed at the Joslyn's Inn which was wonderful and distinctive due to the Round Barn and due to Marge and Ralph Joslyn who were exceptional Vermont natives and became close friends.

The Inn is still operating and carefully modernized by the new owners and the barn has also been preserved. This is on the web at The round Barn

We have maintained our membership in the Mad River Consortium. And, we hope to return for skiing at mad River (skiing if you can!) as times permit.

19

London – 1983

In 1983 due to the merger of UNIVAC and Burroughs we returned to London where I initially took on the role of adviser to Rob Wilmont, the Chairman of International Computers Limited (ICL). My main task was to determine if ICL could be made into a viable computer systems supplier. After careful study Charles Smith and I decided on what would have to be done. Rob read the report and said that he could not make that happen. Therefore, ICL was sold to Fujitsu.

Refer to Section 2 for other University activities.

19.1 Imperial College London

I was offered the newly established Schlumberger Chair at Imperial College. The professorship was one of several professorships that Jean Riboud the Chief officer of Schlumberger had donated. (See his Wikipedia entry at Jean Riboud). Tragically, he died suddenly just shortly after my appointment was agreed and just before I was to meet him in Paris. Of course, I had known of him through contacts and work with Schlumberger. He was one of the heroes of the war period and a dominant force for enlightened development until his untimely death at age 65.

An office and lab space were allocated for me. But, I noticed that a painter had arrived and started to paint my title and name on the office door. I said, politely, that he should just paint my name: Michael Godfrey. This led to some controversy, which I ignored.

19.1.1 AI

An incident during this time was an "important" meeting to discuss the current generation of "AI" work. On opening the meeting I suggested that we compare and contrast "artificial intelligence" with "natural stupidity". This did not go down too well, but was worth mentioning, then as now.

19.2 Final Term at Imperial College

However, sadly, due in large part to Thatcher's hostile and destructive treatment of the Universities it was impossible to work within the College in a reasonable manner. The fact that I had ample support from my Professorship and additional support from the EU Research funding group in Brussels just made matters worse. I did try to offer help within the College, but this was quite difficult. The current rector was Eric Ash who was not competent and embezzled funds from my accounts and, I suppose, others.

I was also able to work with others, mainly at Manchester University and in the US. In any case, I continued my interests in VLSI Systems, both analog and digital. A specific interest was the continuing work on implementations of wavelet transforms for signal processing.

19.2.1 Wavelet Transforms

It seemed that the natural VLSI implementation of wavelet transforms should be based on integer arithmetic since the transform is defined on the dyadic rationals. However, everyone else chose to use floating point even though pretty wasteful of silicon area and energy.

A very good source for wavelet analysis is the text *Wavelet Analysis: the scalable structure of information* by Resnikoff and Wells (41).

19.3 Departure

At this time the administration of the College was in a state of serious dysfunction and corruption. Many senior staff had left. Most prominently David Cox left to Oxford. The prompt step in that was due to Ash's hysterical behavior when Cox was awarded an OBE and Ash was

passed over.

I also chose to leave. The basis for this was that the Rector, Eric Ash, would provide me the funds that he had embezzled in the form of payment of three years to support my joining Stanford. He immediately agreed to this and transferred the funds.

20

Stanford University

In 1989 we moved to Stanford and greatly enjoyed the new environment. I worked in the University and Ilse continued her painting at the Legion of Honor Museum in San Francisco and at home.

20.1 Statistics and Information Systems

I joined the Information Systems Lab. (ISL) in Electrical Engineering and also informally joined the Statistics Department. The move to Stanford was intended to allow me to more fully pursue work in analog VLSI systems and related technologies as well as continue work in statistics. We viewed this as likely a relatively short–term stay, but it continued as a very enjoyable time to 2012 when we decided that returning to London would be best.

20.1.1 New lab within ISL

I established a lab focused on the use of analog VLSI systems for computation and for imaging. This was initially supported by Apple and also subsequently by donations from HP, AMD, and others.

It was very good that quite a few students and visitors joined in the work in this new lab. One in particular was H. Min who visited from China. He appeared at my office and asked if he could help. I assumed that he would just take an interest, copy some papers, and attend some talks as quite a few visitors have done. However, I described my lab and some of its needs in better controlling the various instruments. In principle it was best to have all of the equipment controlled from the workstation computers. I mentioned the lab arrangements and the

computer-based controls that we had so far implemented. Min just said "I could help with that." And, he got to work and made major contributions. He also managed to stay an extra several years. He and his family finally went back to China where he has continued to carry out substantial research.

When acquiring new equipment and lab furnishings I went to the auctions of used equipment being disposed of. A Stanford administrator told me that it was not allowed to purchase used equipment and furnishings. I ignored that, and also I happened to be visiting the AMD development labs with one of the staff who was interested in our work. I noticed a room full of equipment with red tags attached. I knew what that meant and, of course, it was agreed that I could take any items for free. The equipment was typically two or three years old and recently calibrated. This permitted more students being able to work together with excellent equipment.

20.2 IBM OS/2 Development and History

We chose to use the new IBM OS/2 (not the Microsoft product of the same name) for the PC workstations devoted to analog circuit design, fabrication and test. The IBM OS/2 is documented in the book: *The Design of OS/2* by Deitel & Kogan(16). This was a well designed and implemented system which used much of the Manchester MUSS technology. However, we had to change to Linux when IBM was forced by Microsoft to discontinue their own OS/2. This was an important loss to the computing community and more widely. We had to revert to Linux–based systems which were significantly less effective than the IBM OS/2. A history of IBM OS/2 is available at: www.os2museum.com

Be that as it may, we got our work done and the results are in wide use.

20.3 Image Sensing

We implemented a number of analog VLSI circuits for image sensing, wavelet transforms, and other applications.

An important result was a new technique for accurate capacitor charge recording. This was first discovered, designed and implemented by Boyd Fowler. And he did much of the formal analysis and circuit

testing. See the paper *Reset Noise Reduction in Capacitive Sensors* at (19). This technique has wide application in accurately recording for a wide range of contexts. An obvious use is in the cameras in mobile phones. But, uses in medical diagnostic instruments are also important.

I also helped with introducing the use of wavelet transforms where this proved useful.

20.4 New connection through the Museum

Through Ilse's painting we met Bill Fries who, among many other things, was a major donor to the Museum. Ilse first met him when she was painting in the William Fries wing of the Museum. He was not only fun and knowledgeable but also a major donor from his late father's estate.[1]

[1] We think that he may have been a party to the following: A man enters the Fairmont Hotel in San Francisco and states that he is Mr. Fries and asks is a room available. The clerk immediately replies: Of course: we have the top suite where your son always stays. But Fries answers: No just a single room will be fine. You see I am only his father.

20.5 Other Pursuits, skiing of course

An important feature of being in the Bay Area was the opportunity to visit new skiing locations. The immediate bay area was too crowded for us, but we found Mt. Bachelor outside Bend Oregon. This was our kind of place: it was founded in 1958 by local enthusiasts who convinced the Federal Forest Service that they could install a few lifts on the mountain. However, accommodation at the base of the mountain was not allowed. The Wikipedia site is at Mount Bachelor. This gives a full history.

Since there was no accommodation other than a cafeteria and parking for cars there were no crowds and hardly anyone during the week. Obviously, our kind of place. We had many most enjoyable days of skiing. As well as marvelous views over the Cascades.

And, when driving up we from the Bay Area we occasionally stopped off at Crater lake which is a wonder of geology and beauty. The story of the creation of the Lake is easily found on Wikipedia at: Crater lake, Oregon. However, this site does not seem to mention an interesting incident when settlers first arrived from the East. The local Indians said: "Do not go near that place!! It is a BAD place!" Their ancestors were alive to experience the eruption and pass on the event which surely was dramatic and destructive.

And in Bend we accidentally met Edward Hartwick. He was of

German origin but worked in banking in Los Angeles most of his career. He and his mother had retired to Bend. We found that he was widely read, and fun person. In addition he had written two plays! One is a translation and the other an original "political thriller" play.

The translation is of *Don Carlos, Crown Prince of Spain* by Friedrich von Schiller, 1787. We read it, very much enjoyed it and were impressed by the translation. Ed had tried to find a publisher or someone who would organize it for performance, but without success. In any case, his typewritten copy was not of good publication form. I offered to convert it to a more presentable and readable form, using, of course, TEX. This seemed to help some, but Ed was not able to find anyone to mount it for performance.

However, it is available on my Internet Archive page at: Don Carlos, Crown prince of Spain. It is quite popular having been read about 200 times as of May 2025.

He had also written a "political thriller" which was much fun to read. So, I also reset it using TEX. Its title is: *The Thirteenth Madonna*. This is also on my page at The Thirteenth Madonna. It is a well written "thriller" which, surprisingly, is relevant to today's US political upheavals. It has been viewed fewer times (about 200) but it may catch on!

Very sadly, Mt. Bachelor has been taken over by a major conglomerate and now they charge high rates and even higher rates for use of the "express" lane for the lifts. At least, they lost two customers.

21

A Review of Physical Measurement

This Chapter is intended to introduce a review of physical measurement dating from very early times when complex buildings, bridges, aqueducts, walls, and roads were built. Such constructions required accurate measurement. The Wikipedia page *History of measurement* provides a good introduction which indicates that the first recorded measurements occurred in the 3rd or 4th millennium. The same page covers units of length, mass, time, and angles.

How the early builders made the measurements that were required seems in many cases to be unknown. However, accurate measurements of star positions were required for trans oceanic shipping.

The role of Chinese science has been fully described by Joseph Needham. His *Introductory Volume 1* is available on the Internet Archive at: Needham Vol.1 Volume 1 also contains the Contents pages for the subsequent volumes. Volume 3 contains Numbering, Geometry and Algebra, Volume 4 contains Physics, Engineering and Technology.

21.1 Introduction of Modern Measurement

However, a remarkable transition took place starting in the mid 1800's. Much of this was led by Babbage from the time that he held Newton's Chair in Mathematics at Cambridge.

His work also included the introduction of error correcting codes. The full description is provided in his autobiography (3).

Starting at Chapter IV in his autobiography there are are some very useful statements: The quote below has often been mentioned but this is the original statement from his autobiography:

> On two occasions I have been asked,—"Pray, Mr. Babbage, if you put into the machine wrong figures, will the right answers come out?" In one case a member of the Upper, and in the other a member of the Lower, House put this question. I am not able rightly to apprehend the kind of confusion of ideas that could provoke such a question. I did, however, explain the following property, which might in some measure approach towards an answer to it.

It is possible to construct the Analytical Engine in such a manner that after the question is once communicated to the engine, it may be stopped at any turn of the handle and set on again as often as may be desired. At each stoppage every figure-wheel throughout the Engine, which is capable of being moved without breaking, may be moved on to any other digit. Yet after each of these apparent falsifications the engine will be found to make the next calculation with perfect truth.

The explanation is very simple, and the property itself useless. The whole of the mechanism ought of course to be enclosed in glass, and kept under lock and key, in which case the mechanism necessary to give it the property alluded to would be useless.

This passage occurs just before Chapter VI.

Additional results are at Babbage's Wikipedia page: Babbage page. This, however, is at best incomplete, especially concerning his engineering instruments including instruments for recording temperature, velocity, and vibration.

His autobiography is also available on the web at Babbage autobiography.

Of course, his early life and time at Cambridge and the completion of the analytical engine including its formal Register Transfer System (RTS) definition and verification are fully described.

21.2 *Physical Measurements with New Instruments*

Subsequently Babbage addressed the practical issues of making the measurements required in order to measure of the behavior of trains in motion. This came about when he was working with Brunel. While Brunel had the vision of railways spanning much of England, and a tunnel under the Thames river in London, he did not have the technical skill to make these constructions operational and safe. He had limited

skills or interest in the required engineering details. For this he called on Babbage.

It was necessary for the safe operation of the railroads to decide key capabilities such as:

1. The maximum safe speed of the train.
2. Effective braking performance.
3. Maximum gradients.
4. The appropriate minimum rail curve radius, and
5. The best choice of rail gauge.

In order to determine these parameters Babbage built a railway carriage which was instrumented to measure speed, vibration and other physical parameters. This is described in Chapter 25 of his autobiography(3).

The instruments that Babbage invented provided recording of measurement values by a moving pen writing on paper rolls. These are the first known instruments with these measurement and recording capabilities.

The results were used to determine important parameters for the railroads, the construction of the carriages and save speeds of the engines. The measured parameters included temperature, velocity, vibration, turning radius, track gauge, and safe grades.

The pen recorded traces were translated into numerical values using some chosen accuracy. I have not found a more detailed description of this.

21.3 Outline of Babbage's further Developments

After this foundation the improvements depended on more precise instruments and, of course, the consistent storage of each measurement with an appropriate number of digits for values such as temperature, position, vibration and other measurable conditions or quantities.

As time has passed measurements have been recorded with increasing accuracy and precision and typically stored as a large number of digits.

This is also best explained in Chapter 25 of Babbage's autobiography(3). The autobiography is available online at the Gutenberg.org website: Passages from the Life of a Philosopher.

22

Electromagnetism

Electromagnetism provides a foundation for much of Physical Science. However, a key contribution by Ampère had apparently not been translated.

22.1 Translation of Ampère's Treatise

While at Stanford I undertook the translation of Ampère's *THÉORIE DES PHÉNOMÈNES ÉLECTRO-DYNAMIQUES, UNIQUEMENT DÉDUITE DE L'EXPÉRIENCE* (2). Both the original and the translation are to be found at: in English and in French.

My first step was a search of the Stanford Special Collections Library. The Library initially showed in their catalog that they had a copy of Ampère's treatise, but after some discussion it was discovered that they actually had three copies. Thus, I had multiple editions and printings which helped in identifying typos and other differences.

I have taken care to make all of the diagrams clearly readable, and correct. The originals were, due to age, less clear and contained quite a few typos in both the text and the Figures.

However, during my work on this I received an email from Andre Koch Torres Assis, at the Institute of Physics, University of Campinas (Website for Assis) who was also working on a translation. We agreed to collaborate on the translations but keep them separate. Merging the two would have been a lot of work. Andre provided numerous corrections of my draft text and I provided some from his and also I provided my updated diagrams of all of Ampère's quite complex circuits. These required careful editing of both the circuits themselves but also the notations that were referred to in the text.

22.2 *Completion of Electromagnetism*

As detailed below Ampère, Faraday and Maxwell worked very closely together. Ampère made use of Faraday's experimental results and developed the mathematics of electrodynamics along with Maxwell. He explored these theoretical results through a series of carefully constructed experiments. These experiments show the correctness of the theory that he shared with Faraday and Maxwell. See (2) for his full report 22.2.1 or (21) for more details. The Gladstone book is in any case by far the best source for Faraday. It is also available on the web at: Gladstone

Maxwell expressed his view of Ampère's results as:

> *The experimental investigation by which Ampère established the law of the mechanical action between electric currents is one of the most brilliant achievements in science. The whole, theory and experiment, seems as if it had leaped, full grown and full armed, from the brain of the "Newton of Electricity". It is perfect in form, and unassailable in accuracy, and it is summed up in a formula from which all the phenomena may be deduced, and which must always remain the cardinal formula of electrodynamics.*
>
> From: J. C. Maxwell, *A Treatise on Electricity and Magnetism, Dover, New York, 1954, vol.2, p.175* (30)

The French physicists of the time ridiculed the possibility that a mathematician could say anything useful about physics and he had difficulty publishing his results(2) in France.

And Ampère's personal life had serious tragedy. When he was at an early age his father, a local town administrator, was guillotined.

22.2.1 *Summary of Results*

The three: Faraday, Ampere, and Maxwell working together made exceptional breakthroughs within the time span of the 1820's to 1860's, a mere 40 years. The total span of their working lifetimes together was about 53 years: 1826 to 1879.

Life Summary

Author	Life Span	Joint Results
Faraday	1791 – 1867	Electrodynamic Induction
Ampère	1775 – 1836	Phenomena and
Maxwell	1831 – 1879	Field Theory
French Revolution	1789 - 1799	

Ampère, Faraday, and Maxwell shared the results together. It has been usual to describe each of these three scientists as making individual contributions. However, on fuller reading it is evident that they worked very closely together. They frequently met together in London or Paris. While each made individual contributions, the full result was due to all three.

This was made possible due to the fact that Maxwell and Faraday also knew French. This was obviously important as Ampère's book, *Mathematical Theory of Electrodynamic Phenomena* was written in French. Maxwell's French was surely good, as his wife was French! It is not clear which language may have dominated in their discussions together.

Ampère made the key discovery that a wire carrying electric current can attract or repel another wire next to it that's also carrying electric current. The attraction is magnetic, but no magnets are necessary for the effect. He went on to formulate Ampère's Law of electromagnetism and produced the most complete, of his time, mathematical definition of the electric current.

He also proposed the existence of a particle we now recognize as the electron, discovered the chemical element fluorine, and grouped elements by their properties over half a century before Dmitri Mendeleev produced his periodic table.

The unit of electric current, the ampere (A or amp), is named in his honor.

22.3 Michael Faraday: Foundations of Modern Science

There are a great number of discourses on Faraday in books, periodicals, and on the WEB. And, there have been disagreements as to his contributions. No one seems to doubt his genius. One very attractive source on

the web is: https://www.famousscientists.org/michael-faraday. This site provides a full summary of his life and indicates both his character and his accomplishments, but without substantial technical content.

A key feature of his character was his modesty and complete dedication to science. He refused all financial support or honors, saying that this would interfere with his objectivity in his investigations. This and much more is made clear in the nontechnical biography: Michael Faraday by J. H. Gladstone (21)

However, the biography by L. Pearce Williams (52) provides a full description of his life and his scientific work. The publisher's summary on the back cover page reads:

> "This definitive biography illustrates for the first time the full extent of Michael Faraday's monumental contributions to modern physics. For a large part of his life, Faraday was a controversial scientific figure. Though he was applauded for his ingenious discovery that an electrical current could be induced with a magnet, the greater implications of his work were ignored or ridiculed. Professor Williams shows here how the concepts of field theory and the electromagnetic theory of light were central to Faraday's work. Drawing on laboratory diaries and published papers, he corrects the common view of Faraday as a hidebound empiricist, recreating each of his major experiments in step-by-step detail, carefully reconstructing the theoretical links between the discoveries. The story of this fascinating and, in some ways, tragic figure is told in scrupulous detail in this pioneering work."

22.3.1 *Faraday's Diary and Lab*

His Royal Society lectures are available at: Faraday's Diary

Faraday's laboratory has been preserved at the Royal Institution in London. Images of his lab can be viewed at: Faraday's Lab.

Finally, a key feature of Faraday's behavior was that he would never accept payments or other forms of "grant" money. He argued that this would place him in a position such that he would feel a need to produce results which were favorable to the donor.

22.4 *Faraday & the Athenaeum*

Faraday was a founding member and Honorary Secretary of the the Athenaeum Club which was located at: 107 Pall Mall. Faraday also improved the Club's electric lighting.

His wikipedia page is very well done at: Michael Faraday

22.4.1 *Joining the Athenaeum*

I rarely join organizations but I made an exception due to Faraday. I accepted an offer to join the Club. I also mentioned that I would agree to join only if women were also admitted on equal terms. This was completed and I joined.

Initially this worked well. For a time I enjoyed meeting with friends and making use of the Club's facilities.

When I joined Jonathan Ford was the Secretary. He also managed the Ski Club and its trips to Kitzbuhel. He did an excellent job of running the Club as it was intended by the founders.

22.4.2 *The Athenaeum as it has been since during 2025*

However, as the Club is now Faraday's clear guidance would be to have nothing to do with it. I no longer consider myself to be a member even though I am still on their mailing list for events and activities.

In any case I felt uncomfortable with the expansion of the membership to persons with no scientific or intellectual skills or interests.

It also appeared that the management of the Club was ineffective. For example, Wikipedia states: May from Wikipedia May is ranked in Wikipedia in the historical rankings of prime ministers, academics and journalists. Her rank is in the bottom quartile.

I attended a recent (mid 2025) General Meeting of the Club. Theresa May was unable to manage the meeting. Everyone seated near me was obviously embarrassed and uncomfortable. The meeting was closed without any opportunity for comments or questions.

I offered to resign and this was at first immediately accepted. But then it was promptly reversed and I was reminded that I had been

made an Honorary Life Member. However, this seems to have led to disagreement within the Club.

While it seems that I may or may not in some sense be a member I still get correspondence about Club events.

Obviously I am sorry for this episode and hope for full recovery by members who have the will and power to carry out the required reforms.

22.4.3 *The Athenaeum Building*

The building remains of very substantial importance. The architect was Decimus Burton. He included the statue of Athena which is prominent at the front of the building. Due to London planning laws no changes can be made to the exterior.

A very attractive view of the building and the Club is on Wikipedia at: The Athenaeum

22.5 *André-Marie Ampère*

Ampére, a mathematician by training, helped to develop the mathematics of Faraday's electromagnetism. However, most importantly he developed and demonstrated his formal theory through extremely careful experiments. His experimental methods and his commitment to Science are a lesson for us all, even more so today. And, this makes clear his close collaboration with Faraday and Maxwell. See Ampère, *Mathematical Theory of Electrodynamic Phenomena*. Or, in the original French at: Ampère, *Théorie Mathématique des Phenénomeènes Électro-dynaniques*.

This contributed with Maxwell's development of the equations of electromagnetism as they are today. See (30).

22.6 *Maxwell*

Maxwell, Faraday's and Ampère together in order to complete the formulation of Electromagnetic Theory.

The theory was published in: James Clerk Maxwell, F. R. S. Philosophical Transactions of the Royal Society of London, 1865 155, 459-512,

1 January 1865. Available at Maxwell's Dynamical Theory.

And, he refers to Ampère's publication in the Introduction to *A Dynamical Theory of the Electromagnetic Field* See Ampère's Treatise in English translation

22.7 Modern Physics

After an extended period another major step from both the pedagogic and scientific standpoints was the *Feynman Lectures*. These were first given in 1961-62 as the first and second year undergraduate physics course at Caltech. These lectures are now fully available on the WEB. The web site has been created by Michael Gottlieb. It is at: The Feynman Lectures and More.

The web lectures also include a large number of corrections. Feynman was well-known for thinking clearly but saying or writing something different from what he intended. This included the inversion of a ratio or a misplaced term.

At present the online Lectures are very much more accurate than any of the other known published versions.

22.8 Further Exploration in Physics

Based on these foundations recent developments have in large part centered on improved observational capability extending far out in the universe. First the Hubble and more recently the WEBB telescopes have revealed an astounding body of data. These devices have shown amazing ingenuity and technical skill in their construction with the final assembly of the WEBB conducted while after launch. T hese images will be a dominant source of knowledge for years to come. All this, within my lifetime, has never before been experienced.

An interesting Website is at Fourmilab by John Walker. This contains an unusual collection of the views of John Walker who founded Autodesk.

22.9 *A Reservation*

However, a similar development of human nature and its possibilities for a humane management of populations seems practically nonexistent. The opposite of the development in physics appears to be the case. The prospect of human life continuing to exist seems decreasingly likely.

Rachel Carson's *Silent Spring*(13), first serialized in the New Yorker, was an early, but hardly heeded, warning even though some particularly damaging pesticides were also due to pressure from Linus Pauling.

But, further discoveries and warnings of global degradation also seem hardly to have been noticed. We may already have passed the point of no return.

23

Perspectives on Science

While important discoveries were made, particularly in China, from quite ancient times the rate and importance of discovery accelerated in the Western world most prominently due to Huyghens. He completed his discovery of the nature of light in 1678. But he only communicated the results more widely in 1690.

23.1 Coherence

Christian Huyghens first discovered that light in free space is transmitted without any change in the properties of the light. This is termed that light in free space is *perfectly coherent.*

His results are available on the Internet Archive in the original french at: Huyghens, *Traité De La Lumière* and in English translation at Huyghens, *Traité De La Lumière (English translation)*.

The key discovery was based on the observation that light arriving at the earth had the same intensity regardless of how far away the light had originated. While seemingly simple, this observation required careful thought and measurement. It is fundamental to the understanding of the nature of light.

23.2 Introduction to Huygens Treatise on Coherence

Huygens' Treatise reported the coherent nature of light in free space.

The Preface in English translation is reproduced here:

Translator: SILVANUS P. THOMPSON.

PREFACE

I WROTE this Treatise during my sojourn in France twelve years ago, and I communicated it in the year 1678 to the learned persons who then composed the Royal Academy of Science, to the membership of which the King had done me the honour of calling me. Several of that body who are still alive will remember having been present when I read it, and above the rest those amongst them who applied themselves particularly to the study of Mathematics; of whom I cannot cite more than the celebrated gentlemen Cassini, Römer, and De la Hire. And although I have since corrected and changed some parts, the copies which I had made of it at that time may serve for proof that I have yet added nothing to it save some conjectures touching the formation of Iceland Crystal, and a novel observation on the refraction of Rock Crystal. I have desired to relate these particulars to make known how long I have meditated the things which now I publish, and not for the purpose of detracting from the merit of those who, without having seen anything that I have written, may be found to have treated of like matters: as has in fact occurred to two eminent Geometricians, Messieurs Newton and Leibnitz, with respect to the Problem of the figure of glasses for collecting rays when one of the surfaces is given.

One may ask why I have so long delayed to bring this work to the light. The reason is that I wrote it rather carelessly in the Language in which it appears, with the intention of translating it into Latin, so doing in order to obtain greater attention to the thing. After which I proposed to myself to give it out along with another Treatise on Dioptrics, in which I explain the effects of Telescopes and those things which belong more to that Science. But the pleasure of novelty being past, I have put off from time to time the execution of this design, and I know not when I shall ever come to an end if it, being often turned aside either by business or by some new study. Considering which I have finally judged that it was better worth while to publish this writing, such as it is, than to let it run the risk, by waiting longer, of remaining lost.

There will be seen in it demonstrations of those kinds which do not produce as great a certitude as those of Geometry, and which even differ much therefrom, since whereas the Geometers prove their Propositions by fixed and incontestable Principles, here the Principles are verified by

the conclusions to be drawn from them; the nature of these things not allowing of this being done otherwise. It is always possible to attain thereby to a degree of probability which very often is scarcely less than complete proof. To wit, when things which have been demonstrated by the Principles that have been assumed correspond perfectly to the phenomena which experiment has brought under observation; especially when there are a great number of them, and further, principally, when one can imagine and foresee new phenomena which ought to follow from the hypotheses which one employs, and when one finds that therein the fact corresponds to our prevision. But if all these proofs of probability are met with in that which I propose to discuss, as it seems to me they are, this ought to be a very strong confirmation of the success of my inquiry; and it must be ill if the facts are not pretty much as [represent them. I would believe then that those who love to know the Causes of things and who are able to admire the marvels of Light, will find some satisfaction in these various speculations regarding it, and in the new explanation of its famous property which is the main foundation of the construction of our eyes and of those great inventions which extend so vastly the use of them. I hope also that there will be some who by following these beginnings will penetrate much further into this question than I have been able to do, since the subject must be far from being exhausted. This appears from the passages which I have indicated where I leave certain difficulties without having resolved them, and still more from matters which I have not touched at all, such as Luminous Bodies of several sorts, and all that concerns Colours; in which no one until now can boast of having succeeded. Finally, there remains much more to be investigated touching the nature of Light which I do not pretend to have disclosed, and I shall owe much in return to him who shall be able to supplement that which is here lacking to me in knowledge. The Hague. The 8 January 1690.

NOTE BY THE TRANSLATOR

Considering the great influence which this Treatise has exercised in the development of the Science of Optics, it seems strange that two centuries should have passed before an English edition of the work appeared. Perhaps the circumstance is due to the mistaken zeal with which formerly everything that conflicted with the cherished ideas of Newton was denounced by his followers. The Treatise on Light of Huygens has, however, withstood the test of time: and even now the exquisite skill with which he applied his conception of the propagation of waves of light to unravel the intricacies of the phenomena of the double refraction of crystals, and of the refraction of the atmosphere,

will excite the admiration of the student of Optics. It is true that his wave theory was far from the complete doctrine as subsequently developed by Thomas Young and Augustin Fresnel, and belonged rather to geometrical than to physical Optics. If Huygens had no conception of transverse vibrations, of the principle of interference, or of the existence of the ordered sequence of waves in trains, he nevertheless attained to a remarkably clear understanding of the principles of wave-propagation; and his exposition of the subject marks an epoch in the treatment of Optical problems. It has been needful in preparing this translation to exercise care lest one should import into the author's text ideas of subsequent date, by using words that have come to imply modern conceptions. Hence the adoption of as literal a rendering as possible. A few of the author's terms need explanation, He uses the word "refraction," for example, both for the phenomenon or process usually so denoted, and for the result of that process: thus the refracted ray he habitually terms "the refraction" of the incident ray. When a wave-front, or, as he terms it, a "wave," has passed from some initial position to a subsequent one, he terms the wave-front in its subsequent position "the continuation" of the wave. He also speaks of the envelope of a set of elementary waves, formed by coalescence of those elementary wave-fronts, as "the termination" of the wave; and the elementary wave-fronts he terms "particular" waves. Owing to the circumstance that the French word *rayon* possesses the double signification of ray of light and radius of a circle, he avoids its use in the latter sense and speaks always of the semidiameter, not of the radius. His speculations as to the ether, his suggestive views of the structure of crystalline bodies, and his explanation of opacity, slight as they are, will possibly surprise the reader by their seeming modernness, And none can read his investigation of the phenomena found in Iceland spar without marveling at his insight and sagacity.

S. P. T.

June, 1912.

23.3 Information Contained in Photons

Poynting explained the properties of light in his paper *The Wave Motion of a Revolving Shaft, and a Suggestion as to the Angular Momentum in a Beam of Circularly Polarized Light* (39). This paper is also available at: archive.org. It points out that photons have a large number of degrees of freedom due the orbital angular momentum states. Thus a

single photon can contain and transmit an indefinite number of bits of information.

This is in conflict with what has been the established view as, for example, expressed by Denis Gabor that photons have only 2 states and therefore can only hold one bit of information. See his paper which is available at: Communication Theory and Physics, Trans. IRE Professional Group on Information Theory, vol.1 no. 1, 1953) (20).

More about this is also available in my library on the Internet Archive at the paper: Noise and Information.

24

Transition of Information Technology

At this time, approximately mid-1800's, there was a fundamental transition of the technology for making physical measurements. Initially measurements were all marked as lengths or written as numbers to represent length, weight, etc. These were all analog in the sense that they were a sample of the measured value taken at a specific time and recorded on some physical medium. These were imprecise despite very careful and difficult steps. Typically, an error estimate was produced in the form ±<error estimate>.

By the end of this period measurements had predominantly been transformed to being recorded in digital form with an appropriate number of digits.

While noise still exists in all physical systems, the digital methods provided a fundamental improvement. And, it was and is, at least for "static" measurements quite simple to repeat the recording any number of times in order to assess and improve the accuracy.

The analog to digital conversion was fundamental to the advancement of scientific knowledge. Babbage foresaw and made use of this development. And this motivated his development of his digital computer. In any case, Babbage's contributions have been essential to Engineering, Instrumentation, and more. This is described in his autobiography (3). It has been surprising to find that none of the commentators concerning Babbage and his works seem to have read his autobiography. It was just recently republished by Cambridge in its relatively new *Cambridge Library Collection* which has republished important works by means of image enhancement of copies of the original first editions. This has avoided new typographical errors and greatly enhanced the image quality. This shows Cambridge Press at its best, as usual!

24.1 *Publication of Academic works*

Wide dissemination of scientific knowledge is essential. However, controls are needed in order to provide incentives. At one end of the scale Princeton Press restricts unpaid access to all of its publications using the most recent extensions to the period of copyright to all of their publications. It appears that nothing that they have published is free of copyright restriction. Princeton Press authors cannot distribute PDF copies of their own work without full payment for each copy.

Princeton University has made outstanding improvements in their handling of access for students by, for instance, opting out of the student loan program. Sadly, they allow the University Press to be opposed to wider knowledge.

On the other hand Cambridge Press has a policy which allows authors using a book that they have been writing for a course to also allow students to freely refer to and download PDF copies for the course text. When I discussed this with a Cambridge Press staff member they reported that this was fine with them and they found that this also increased the sales of hard-copy editions of the book. Reading a "real" book is still a pleasure.

24.2 *After Vietnam*

This period saw, finally, the end of the Vietnam War and there was a feeling that lessons had been learned and a more peaceful and productive period could prevail.

However, by the late 1960's the introduction in the US of student loans through a Federal initiative contributed substantially to the tragic consequences seen today.

My initial involvement in this was attendance at the Faculty meeting at Princeton which had on its agenda the offer of Federal support through a Student Loan Program. I spoke and said simply that this was the dumbest idea that had ever come to my attention: it should not take us more than a minute to firmly reject the offer of this plan and continue to admit students based solely on merit. I was stunned to find that I was overruled. The program went ahead and continues to cause immense hardship for a large part of the population particularly of course, the poorer students who need support the most. That, coupled with the extreme increase, by roughly a factor of ten after inflation

adjustment, in the cost of university education has resulted in a less well-informed population, and for many a lifelong severe disadvantage.

However, after a long period of distress for many students, Princeton was the first of the Big Name Universities to discontinue offering student loans. Instead they offer financial support as needed for all admitted students. At that time the other Universities, such as Stanford, were outraged, claiming, despite contradicting evidence, that only Princeton could afford such generosity.

It is worth noting that quite a few excellent, but less prominent, schools such as Amherst and Williams College, never joined the loan scheme and continued to provide excellent education. When I was at Deerfield the Headmaster sent quite a few students to these Colleges. He knew that they would get an excellent education without many of the pressures of the big-name schools, and that this would much better meet their needs.

When I offer advice to candidate students I make clear: only consider Universities that do not permit student loans. Sadly, that excludes all UK Universities where the loan system has been applied in a particularly egregious manner, reducing students to penal servitude often for the rest of their lives. No sense of a Golden Age for them. Instead for them the only question on graduation was and is: How do I find a job to pay off my loans? And, will I ever have control over my own bank account and finances? I found that I could not answer those questions from students. Working at a hedge fund is not good enough.

The attempt in the US to reduce the loan burden was initiated by Biden, but has been abandoned. There is a desperate need for well-trained and well-paid teachers with suitable facilities, but there is no sign that this can be made to happen in the foreseeable future. A teacher's salary typically does not meet the the loan payments with much left over.

24.3 Convenient Travel

In these times travel was by rarely fully booked aircraft and using "standard" tickets due to the fact that prices were regulated for all commercial flights. A ticket was valid for each flight between each origin and destination. The formal term for this was *Interlining*. [1] Thus, any ticket for the same route was valid on any airline. Therefore it was a handy practice to arrive at the airport, check the departures board

[1] Interlining made travel easy.

and board the next flight to the planned destination.

The correct allocation of funds was as follows: All tickets were printed on the same stock paper so that they all weighed the same regardless of the named carrier. Since prices were regulated all carriers charged the same in any case. The tickets, of course, named the carrier from which they were purchased. So, when accounting was done the tickets used by each carrier were put in sacks and weighed. Thus, with these records of how many tickets were sold by each airline or ticket agent, the correct allocation of funds to each airline could be provided.

There has been thought of bringing back Interlining. See the IATA report: IATA Interlining Report.

24.4 Evolution of Social Structures

Curiously, wide divergences also show up in the evolution of societies. There are two such divergences which uniquely characterized my experience. First, the real cost of University education where I was educated increased, after adjusting for inflation, from 1955 to 2021 by a factor of 7.4. This is substantially less than at many other "leading" Universities. At today's prices many students who would have qualified can no longer afford the cost. Second, CEO compensation in real terms from 1978 to 2019 has grown by 1167 times while average employee compensation in real terms has grown by 13.7%.

This causes the monetary incentive to appear to be a successful manager to greatly exceed the incentive to actually do work. An obvious way to appear to be a successful manager is to manipulate an IPO or a merger. Developing and producing valuable products and services is not seen as a most effective method for creating a best appearance for an IPO.

Luckily I spent nearly all of my career doing actual work and was, I thought, fairly rewarded for my work. This seems hardly be possible today.

24.4.1 Regulation of Elections

The FEC regulation of election funding has become unfair in that any individual acting separately can contribute only one vote, but a corporation, can contribute by various means as many votes as they

choose to buy. Even the relaxed rules are bypassed. Thus individuals such as Thiel, or Musk acting through corporate entities can fund the election of individuals of their choice. This does not always work, but it is obviously in conflict with the "one person one vote" principle.

The full set of regulations are found here: FEC Regulations. In effect the rich and corporations get as many votes as they choose to buy.

This provides evidence that those of my age have lived as I have in a now gone Golden Age.

24.5 Continuing Loss of an Educated Population

The quality of education has suffered very seriously while the needs for improved education due to the increasing complexity of our surrounding continues to increase. This is most prominent in the US where student knowledge has been measured at about thirty percent below in math skills as compared with UK students as reported in a recent Financial Times report.

The problems in the US start with early schooling in dilapidated buildings which are repaired by the teachers in off hours. The books are out-of-date and held together with tape. Then there is a progression to University which is about 8 times the real cost from the time when I was at University. This can, in many cases only be covered by student loans which lead to penal servitude for many years. (For this see: 13.6) The state of schools has been fully reported on CNN CNN Report on September 18, 2022. This report gives the schools a D+ due to unsafe, unhealthy, and inadequate facilities. And, of course, the inadequate salaries of the heavily overworked teachers adds to the problems.

At present more Universities are opting out of the student loan scheme which helps some. (Again see: 13.6) But the 8 times cost increase must be paid for, or the cost must be reduced. The extreme differences in incomes is a part of the problem. While it has not been possible to obtain relevant data it seems evident that the ratio of a University Professor's salary to that of a school teacher's has increased by a large multiple.

How can a student look forward to a bright and productive future under these conditions?

There is one ray of hope with respect to serious teaching of mathematics: a few years ago Gilbert Strang, who has taught mathematics

at MIT since before time, finally decided that Linear Algebra had an important role and this is now taught by him at MIT. His linear algebra book is also widely used at other Universities. It could also be introduced much earlier, but this would require teachers who know or can learn the subject. This is important since all computers as used by many students and others depend on linear algebra for many common tasks.

24.5.1 Loss through Social Media

However, more recently the children share on the web through social media, but each one has an experience separate from the rest of the family.

The loss of shared family experience is devastating for the family and for wider social coherence. The current increase in violence seems at least in some part to be caused by this fragmentation. While this has been widely recognized there seems to be no substantial effort to ameliorate the negative effects.

See also 24.5.1.

In conclusion it is essential to view the eloquent summary by David Attenborough. This is available on Netflix from the Wikipedia page: Breaking Boundaries.

And he has recently produced a more compelling analysis: David Attenborough: A life on our Planet: Attenborough: A life on our planet

This may require searching on Netflix or elsewhere.

24.6 A Prelude: AT&T

This prelude is appropriate as AT&T played a prominent role in scientific research and provided the environment for much of my life's work.

24.6.1 History

AT&T started providing telephone services in the US in 1877. At that time there were a number of companies offering competing services.

This was not entirely convenient as the separate services did not interconnect. A review of this early history is available at the Wikipedia site: Early AT&T founding and development. The later part of this WEB site, particularly concerning the divestiture of AT&T, is inaccurate. Most importantly it does not mention the role that IBM played in initiating and driving the divestiture.

From its founding the company quite quickly established itself as the near monopoly provider of wired communications services in the US and also very briefly internationally.

24.6.2 Universal Service

AT&T from its foundation offered services to "everyone".

AT&T was unique throughout the world in offering telephone service to everyone who was within the area that they could serve. This meant service was offered to everyone who wished to connect. Telephone lines were strung across long distances in order to provide this service. Initially, in rural areas these were "shared" services, i.e. there was one wired line connected through a number of homes. This meant that the parties shared the line when communicating with another party on their wire or outside to another party elsewhere. But, of course, this also meant that any party could "listen in" on any current conversation on the same line. For the most part this worked fairly well and even in some cases increased the strength of the "community" on the line.

This contrasts with much of the rest of the world where telephone services were only provided to major businesses and to sufficiently wealthy and prominent persons. This restricted availability was still in effect in the UK when I arrived in 1959. I was told that a person like me should not expect telephone service. Of course, AT&T helped out by mentioning my case to BT. The phone was then promptly installed. I did need a phone.

As an aside, when AT&T introduced direct distance dialing to phones anywhere within the AT&T network they were surprised that this service was so little used. A study was undertaken which produced the result that a large fraction of customers did not know anyone outside their local community.

24.6.3 AT&T expansion

Separately, but quite quietly, AT&T also started expansion in Europe and other parts of the world. This development was, after a time, wound down for various reasons, but remnants remained. For example, they continued to operate the cables and terminations at both ends of most transoceanic cables. This came in handy for me when some service upgrades were needed. Also, when satellite links were established it was helpful to know the prefix code to force oceanic cable connection for transoceanic calls. The time delay for the satellite path was and is long enough to make conversation somewhat difficult. By now the transcontinental paths in general use fiber optic cables. See the Wikipedia page: Communication cables.

24.6.4 The Task at AT&T

My interest in how things work led to a major opportunity when I was asked to help determine the economics of the world's largest Company (AT&T). More precisely the task was to determine the long-run choices for the Company in order to provide the most efficient services and to satisfy the rules provided by the FCC (Federal Communications Commission). The company had approximately 1 million employees and provided communications services for the United States. Substantially more than 300 million customers, both businesses and individuals, were being served on a continuing basis.

As AT&T had established a monopoly it was decided to undertake a Federal Investigation by the FCC under the heading "Communications Inquiries" which took place starting in the 1960's". This led to continuing Federal supervision. The agency for this supervision was the Federal Communications Commission (FCC). The Wikipedia page that describes much of this, from an "outside" perspective is FCC Inquiries. However, it fails to make clear IBM's intentions which were to prevent AT&T from providing anything other than analog voice communications.

My formal role started in 1967. The task presented to me, as mentioned above, was to help to determine the long-run incremental costs of of the message toll telephone services for the US. This information was required under FCC regulation so that the FCC could determine if AT&T was acting fairly and not using its monopoly status to the disadvantage of any customers or other businesses. Working with a small and exceptionally talented and knowledgeable group at AT&T corpo-

rate headquarters in New York City we completed our task and gained full acceptance by the FCC. Not only did they accept our results and confirm that AT&T was acting in accordance with the regulatory rules but they also asked if they could obtain a copy of our computer system which provided the required information. AT&T agreed to provide all the required information and the FCC acquired a computer system which was identical to the one we used. Thus they could validate our reported results and conduct their own analyses.

In addition, this helped to reduce the costs of communication for many people and businesses. By the end of this period this included voice, telex and related services and access to computers by individuals and other computers. The publicly available report on this work by Robert Breedlove and myself is available on the Internet Archive at: An Incremental Cost Model of Message Toll Telephone Services (https://archive.org/details/MTSBook/mode/1up).

25

Mathematical Engineering and Statistics

25.1 Introduction

A fundamental change took place in Engineering starting in the 1960's. The people involved included Wiener, von Neumann, Shannon, (Claude Shannon) Tukey, and many others. Essentially, the change was the mathematization of practical engineering work. Previously, engineering had been done by "trial and error" guided by basic mechanical and electrical laws (Newton, Maxwell, Heavyside, etc.). Very simplified equations were used to guide construction, but various prototypes were often required to test the guesswork and approximation. Major errors were made: bridges failed (See: Tacoma Narrows Bridge (1940)),[1] steam engines exploded, aircraft crashed. Many due to the failure to accurately understand and model the constructions.

[1] Bad luck with Bridge Construction

This has been documented by many authors, but Wiener and Kailath in particular have emphasized and described the change that came about when computational resources allowed accurate modeling of complex systems.

25.2 Mathematical Engineering

Previously the role of mathematics and statistics in engineering was to fit simple measurements to very simplified equations. In any case, a universal rule was, after estimating a design parameter for its suitability in terms of some form of strength, the parameter was multiplied by a factor of 2 "to be safe." This only worked some of the time. And, the role of statistics was minor and rarely contributed to the avoidance of any of the important errors. Many examples of major failure are

well-known. One less well-known was the total failure of the first electronic telephone exchange. This occurred in Trenton NJ.

The previous electromechanical exchange was widely advertised. The switch to the new system was done during the night. Many customers decided to "tryout" the new system. By mid-morning the new electronic exchange was overloaded and became inoperable. All the circuits had to be rewired back to the old exchange. Not enough was known about the behavior of the exchange systems so that statistical analysis could have predicted the failure.

Today, very few major systems are designed other than by precise modeling. Mistakes are still made, but they play a fundamentally different role since the behavior of the system is predictable. One of the worst recent failures was the wing structure of the Boeing 787. A major error was detected during assembly and led to several months of delay. A key fact is that the error was immediately understood and correction was, in principle, straightforward.

However, a new problem comes with this precise modeling: no one understands the model. Previously, the engineer working out a hand analysis understood in detail (not much detail, of course) what was happening. Today, the internal operations of the models are understood by no one. This becomes more prominent in cases where the origins of the data are also not understood. This is the case for the current Laser interferometer Gravitational-Wave Observatories (LIGO).

25.3 Complexity

In the past, statistics in engineering dealt with simple relationships which could relatively easily be understood. Today the effective statistical methods must deal with complex and strongly nonlinear systems which are typically represented by very large finite-element structures or highly nonlinear systems of equations representing hundreds of millions of electronic components, or very large amounts of experimental data, such as the LIGO.

Overall, the assessment of errors is near impossible to show in a fully convincing way.

At present the James Webb telescope is the most ambitious effort. See the build and launch construction at WEBB construction

25.4 Correctness

In any case, for digital systems, there is a very simple requirement: All results must be "bit-correct." There is no other valid state.

The statistical tools to address such problems have only recently been developed and are not as well-known as they should be.

25.5 The Nature of Information

Information is a fundamental property of Nature. It is defined by the determined arrangement of things. It is transmitted by means of energy transactions. The total possible arrangements are called the degrees of freedom of the system. The number of distinguished degrees of freedom is bounded by noise.

25.6 Information and its arrangement

Error is inherent in information. However, von Neumann stated: "The present treatment of error is unsatisfactory and ad hoc"[1]. It is the author's conviction, voiced over many years, that error should be treated by thermodynamical methods, and be the subject of a thermodynamical theory, as information has been, by the work of L. Szilard and C. E. Shannon(45) (46) and C. E. Shannon (45).

[1] Section 5.2 in von Neumann, 1952. (50)

The present treatment falls far short of achieving this but it assembles, it is hoped, some of the building materials, which will have to enter into the final structure.

von Neumann further expressed the current state of understanding as:

> "Today we are beginning to realize how much of all physical science is really only *information*, organized in a particular way. But we are far from unraveling the knotty question: "To what extent does this information reside in us, and to what extent is it a property of Nature?"

Today's evidence suggests that the Universe is composed of discrete mass-energy objects. These objects have a characteristic "wave" behavior. While they are observed as waves, they equivalently propagate

energy. They may also have various symmetry properties. For an early discussion of this see Beth (6).

25.7 *Fundamental Properties*

•Measurements to an infinitely small scale cannot be possible using instruments which themselves are made of discrete particles and which can only measure over a limited bandwidth. Thus there is a fixed limit to the precision of measurements.

•This also implies that using "exact" relationships, such as orthogonality, is inappropriate. A set of measured points can only be viewed as having an approximately orthogonal basis. The degree of approximation is related to the size of the elementary objects and therefore is related to Planck's constant, h.

•The invariance properties which derive from the symmetry properties of objects determine the behavior of objects in space-time and determine the underlying physical constants. This was recognized in many specific cases starting with Boltzmann. The general theoretical structure was provided by Noether. The present understanding of the physical world has a long history.

Hugyens(25) in the 17th century pointed out that the uniform brightness of distant stars implied that light is coherent: it arrived though free space unchanged. The implications of this are still not widely appreciated. And, the central role of *noise* and *information* is of quite recent origin. The first substantial insight into the role of information was Szilard's 1929 paper (46) (The English translation appeared in 1964) (47).) This paper points out the essential role of information for the understanding of the Maxwell's Demon problem. Birkhoff and von Neumann in 1936(9) pointed out the need to understand the logic of experimental evidence. Subsequent to this paper von Neumann intended to develop this reasoning much more fully [2]Miklós Rédei (40) and made clear in his correspondence also edited for publication by Rédei. Tragically, von Neumann's untimely death prevented this. Much of Jaynes' work (for example his posthumously published book (28) or his "Probability in Quantum Mechanics") (27) was directed to the same goal.

[2] 2

However, Jaynes made major contributions by demonstrating the role of LaPlace, or Bayes, probability in physical science, particularly in quantum mechanics. However, his strongly held view that *only* Bayes

theory, in the form of the maximum entropy principle, was useful for the understanding of data samples did him and his underlying cause much harm. Simply put, sampling theory is useful in making inferences from samples. Jaynes claim that maximum entropy could find meaning in meaningless economic data was mistaken and damaging to his credibility.

The presumption of the oscillator behavior of matter and the resulting random variation of radiation energy came from Boltzmann thermodynamics, and from measurements of radiation in the late 1800's. Physical *entropy* was essential to understanding radiation. Information entropy was only introduced in 1948 by Shannon (45). However, the idea that matter is composed of discrete units originated in ancient science, based on the 'rarification and condensation' properties of matter. Schrödinger (44), pp. 54, provides a concise summary of this history. The observed contraction and expansion of matter could only be explained if it were made of particles which could be spaced nearer or farther apart.

However, only in 1900 was this converted to quantitative form supported by a substantial body of experimental evidence.

The properties of noise and information derive from the basic structure of matter and energy. It appears that the description that is simplest and is most closely consistent with empirical evidence is that matter and energy are interchangeable. They are transmitted as wave packets. Wave energy, or *radiation,* occurs in discrete units. The elementary unit is given by Plank's constant, h. The indivisibility of mass-energy leads to the view that energy is transmitted by discrete radiation *transactions.* See Cramer (15), Einstein (17) and Mead (33).

Today, all of physical science derives from these facts. In addition, since *information* is the determined arrangement of matter, indivisibility leads to limits on the amount of information that may be stored, gained by a measurement, or transmitted from one place to another.

Planck's discovery that black-body radiation is quantized opened a long debate about how this radiation comes about and how it was transmitted. The debate is far from over. Planck's formula yields the mean energy density radiated from a body in thermal equilibrium: ν is wavelength, k is the thermodynamic (Boltzmann) constant, and T is the absolute temperature.

26

Babbage's Digital Computer

Babbage introduced the defining characteristics of a digital computer.

He used his formal notation for the detailed description of the computer that he planned to build. And he proved it to be correct using his verification language.

These were formal design notation and verification methods which are all in use today.

He discusses his "Mechanical Notation" in Chapter IX *On Mechanical Notation* in his autobiography (3) on pg. 142. This, in modern terminology, makes use of a Register Transfer Language (RTL).

26.1 Babbage's Use of his Register Transfer Language

After Babbage implemented his Register Transfer Language (RTL) to his satisfaction he used it to verify the correctness of his completed analytical engine. The paper which describes the language[1] is also available at: archive.org. This paper fully describes the RTL which he had developed and used in Ch. IX to verify his computer implementation.

[1] *XVIII. On a method of expressing by signs the action of machinery, by Charles Babbage, Esq. F. R. S., Communicated January 17, 1826, Phil. Trans. Royal Society, V116, pgs. 250-265, 1826.*

In the mid to late 1800's Babbage had completed the design and verification using his RTL, and partial construction of a digital computer (his "analytical engine"), which was capable of, for example, computing on the data acquired for Brunel and for all other computations on numerical data.

It is often stated that Babbage did not complete the analytical engine[1]. The design was completed and formally verified. This is even today considered to be the conclusion of the definition or a new system.

[1] The London Science Museum staff have made the claim that Babbage did not complete the Analytical Engine. Apparently they have not read Babbage's autobiography.

At this point only the final construction remained to be completed.

Use of RTL continues to be standard computer design practice today. However if a source for the first definition of RTL is indicated it is usual to assign credit to Seymour Cray at UNIVAC as the originator in the early 1960's.

In addition Babbage's work, particularly his computer, was widely studied on the Continent. And, several computers based on his descriptions were built at Universities on the Continent. This has not been widely reported, but deserves further study. Babbage made a number of trips to join in these studies.

26.1.1 A quote about errors

Finally, the following is very often quoted inaccurately. The correct reference is:

"On two occasions I have been asked by members of Parliament, "Pray, Mr. Babbage, if you put into the machine wrong figures, will the right answers come out?" I am not able rightly to apprehend the kind of confusion of ideas that could provoke such a question."

The reference is on page 67 of Babbage's *Passages from the Life of a Philosopher* (3) This the Cambridge Press re-imaged (**not re-typeset**) edition.

27

Exceptional Contributors to Science

Four people are grouped together here as they represent in unusual ways important contributions which have not all been widely recognized.

These are Nyblén, Keynes, Morgenstern, Hedy Lamarr, and Michael Gottlieb.

27.1 Nyblén

Göran Nyblén wrote as his PhD. thesis *The problem of Summation in Economic Science*. He subsequently published the thesis as a book with the same title(37). The book is long out of print but it is available in my library at the Internet Archive: The Problem of Summation in Economic Science.

The Acknowledgments page reads:

> This study was initiated in the academic year 1948-49, when I was working at the Lund Institute of Economics; it was further developed during the year 1949–50 in the course of my stay in the United States on a scholarship, granted by the Swedish Social Science Research Council; it assumed its present form in the year 1950–51 at the Lund Institute of Economics; and it was finally submitted as a doctoral thesis at Lund University in September 1951.
>
> Only the errors and opacities in the volume are completely my own. I cannot possibly express in adequate terms my

debt to my teacher, Professor *Johan Åkerman,* Lund University. His guiding influence has been indispensable in bringing the analysis up to whatever level it has attained; his warm personal interest in my work has been a great encouragement. I should also like to acknowledge the interest shown me by the following scientists of the American universities which I visited: Professor *Wassily W. Leontief,* Harvard University, Professor *Jacob Marschak,* the University of Chicago, Professor *Oskar Morgenstern,* Princeton University, Professor *John von Neumann,* the Institute for Advanced Study, and Professor *Paul A. Samuelson,* Massachusetts Institute of Technology. Particularly I wish to thank Professor Morgenstern for most instructive and stimulating discussions.

I further extend my thanks to Mr. *C. Montagu Evans*, M. A. (Cantab.) for improving my English, and to Mr. *Wilhelm Trotzig* for seeing the volume through the press.

Lund, September 1951. Göran Nyblén

Morgenstern introduced me to this work which is a key contribution to understanding how economies function. It is based on the use of Game Theory to study how individuals and groups act in ways that they perceive as most beneficial or appropriate for them. It is then the combined effects of these groups that produce the behavior of the economy made up of all the groups. This is fundamentally different from the classical macro economics, based on Newtonian Mechanics, which is still in use today.

Tragically, Nyblén died shortly after completing the publication of his PhD. thesis in book form.

It is hard to understand how this work has been overlooked.

The book is available on the Internet Archive at: The Problem of Summation in Economic Science. This is a copy which I converted to TEX format and then to PDF. Copies of the original are still available at the usual used book web sites such as Abe Books.

However there is no indication that its formulation has entered the mainstream of economics, or even received a mention or reference. Most economists are slow to learn: they uniformly ridiculed Game Theory for many years and rarely refer to it beyond simple 2-person games.

When the Nobel Committee award for Economics was first established a few economists recommended including Game Theory. However the Committee responded that their advisers reported that Game Theory had nothing to do with economics. When in 1994 they decided to include Game Theory they failed to choose a main contributor.

27.2 *Keynes*

John Maynard Keynes was one of the very few people making substantial contributions to economics. He also contributed to Probability Theory. And he has been quoted as saying: "In science the workers build on the work of their predecessors. But in economics the workers stand on each other's feet."

This can be considered to be a bit unfair: economics is a difficult subject. The simplifications used in practice and in teaching tend to be counterproductive. Keynes was one of the few who recognized the limits, but he was also able to provide useful results. For example his work at the League of Nations.

Here is a short example of his resolution of an economic problem.

J. M. Keynes: **The Parable of the Stones**

> There were two islands in the South Pacific, one downwind of the other. Therefore, the climate of one was quite different from that of the other. Thus, they grew different crops and therefore a lively trade existed between the two islands. The trade was paid for in large flat stones which were transported between the islands. All went well until a storm blew up as a transport barge entered the harbor. The ship, with all the stones, sank. Since there were no longer sufficient stones to pay for goods, trade stopped and both islands fell into a deep depression.
>
> After some time, a wise-man from one of the islands said: "On clear days we can see and count the stones at the bottom of the harbor. And, therefore, we can keep a record of the ownership of the stones. And thus we can adjust the ownership as transactions are made."

Everyone agreed, trade resumed, and prosperity was restored.

This also helps to explain the nature of liquidity: On cloudy days liquidity is reduced since it is hard to see the the stones clearly. Extra time is needed.

Of much greater importance, Keynes severely criticized Tinbergen's econometric study at the League of Nations. Tinbergen had attempted to use macro econometric methods to model a Nation's economy. Keynes opposed uss of such macro-econometric equations to model the economic behavior of Nations. See a brief summary of this at: John Maynard Keynes. It continues to be a negative aspect of economics that such macro-economic equations are in use. The justification of these equations requires that national economies behave as if they were governed by the laws of physics.

As mentioned above, Nyblen's(37) formulation is far better.

Finally, the exchange between Keynes and Harrod is available here: Keynes-Harrod

Keynes had a sense of humor: He has been quoted as saying:

> In the physical sciences today's leaders stand on the shoulders of those who worked before them. In economics everyone stands on each other's feet.

I am sure that I have heard this quote, likely from Morgenstern. But I could not find it through any Google search or elsewhere.

27.3 Morgenstern

Morgenstern has not been as well-recognized as should be. Without his contribution Game Theory(51) would almost surely not have been developed as it did. While von Neumann contributed the bulk of the mathematics in the book, Morgenstern developed and explained its meaning and context. I happened to find (in the attic of the building housing the Econometric Research Program) the apparently final draft of the Game Theory book. It was entirely written in Morgenstern's handwriting. Of course, I gave the copy to Oskar.

In addition his contribution to the analysis and meaning of economic data is a major contribution. See *On the accuracy of Economic Observations*(35) This work studies a wide range of economic data. It shows that economic data are very often inaccurate and misleading.

I added some observations on this topic. The paper, *Why Economists*

Cannot Predict the Past is available at: Why Economists Cannot Predict

27.4 Gottlieb

While visiting Caltech Ilse and I met Michael Gottlieb and since then we have greatly enjoyed his company and working with him. And, I have benefited from his knowledge and exceptional skill in mathematics (in which he is self-taught – only Feynman might have done as good a job!).

He solved the Feynman spinning plate problem right away. (Feynman when at Cornell observed a student in the cafeteria spinning a plate. The plate both spun and precessed (wobbled, technical term) so Feynman asked "what is the ratio of the spin and the precession rates?".[1] Gottlieb knew the answer immediately. He is also an exceptionally skilled programmer.

[1] For the curious, the ratio wobble/spin = 2

27.4.1 The Feynman Lectures online

Most importantly, Gottlieb has created and manages the Feynman Lectures on the Web. The lectures are at: The Feynman Lectures. This is the definitive site for the lectures.

This site provides the 3 volumes of Feynman's Lectures(18) very much updated by Gottlieb's typo corrections. He also welcomes corrections from readers and, of course, corrects the "corrections".

It is well-known that Feynman knew what he intended to say, but often introduced "transcription" errors when writing.

These 3 volumes are typically being studied by thousands of viewers who spend substantial time, often at least half an hour or much more during each session, studying the material. And, the website is referenced for teaching at many schools.

It is reasonable to suggest that an important part of learning physics throughout the world takes place on this website.

Also, on the website are Feynman's *Tips on Physics, Exercises for the Feynman Lectures on Physics*, *Six Easy Pieces* and the *Messenger Lectures* given by Feynman at *Cornell University* in 1964. These lectures, required considerable editing to make them both clearer and closer to the original recordings. They are at: Feynman Messenger Lectures.

In any case, the lectures are fun and informative: something for everyone!

Following these are additional Lecture Recordings, Photos, and Notes. And, finally, the Original Course Handouts from 1961-63.

In addition, Gottlieb is an excellent teacher!

27.5 Hedy Lamarr

This may seem a bit off the track of this review but Hedy Lamarr was exceptional and deserves much more recognition within the scientific and specifically within the secure signal processing community. Her first profession was in acting. She became famous (infamous in some eyes) for her lead performance in the film *Ecstasy*. It's review on Wikipedia is at: Ecstasy. This review is not too accurate on the implementation of spread spectrum communicates which she invented with George Antheil.

This secure communication method was widely used by the allies for communications during WW2. However, the invention was classified at a high level and even after the war she was not allowed to make her invention known nor, of course, to patent it. She could not even mention anything about her work. This continued until her death.

A summary of her life is on Wikipedia at: Hedy Lamarr.

27.6 An event on the way to work

Just to close this Chapter, on 7 August 1974 on the way to work walking by the twin towers in downtown Manhattan I noticed a crowd looking up. What they saw was a highly skilled tightrope performer walking across between the two towers. His wire was tied at each tower at the top. He was obviously a very skilled performer. So, I walked on to work. Later in the news I read that he had been arrested. But, the judge sentenced him to perform for children in Central Park for a number of days! So, all was well!

28

Study and Development

At an early age[1] I also started on an exciting period dealing with matters outside strictly academic work. Change was in the air and exceptional advisers and guides helped me at every step.

[1] Learning to be helpful

A guide to helpful behavior is shown by this event: Einstein had agreed to meet a student at a bridge in Berlin. He arrived, but the student only arrived quite a bit later. The student started to apologize but Einstein interrupted and said "No problem, I can think anywhere".

And, on this subject, a profound message from Einstein is included as the Preface to Max Planck's book: *Where is Science Going?*. This preface is available in my Library on the Internet Archive at Where is Science Going.

28.1 The History of Instrumentation

It has been a unique privilege to live in the age of rapid development of instruments for measurement of physical properties. This was initiated by Babbage (3) in the mid-1800's. He invented and developed the recording oscillograph and associated mechanisms for sensing temperature, pressure, and vibration. For example, it was these contributions that made Brunel's trains sufficiently reliable and safe.

During my early lab experience these instruments were refined through several generations for analog recording on paper, film or other media. Then came the digital revolution so that the time-based and accurate values could be recorded to high precision. Essentially, the quantum limit was reached. Including, of course, the information contribution made by Poynting (39) .

Poynting, in the paper cited above, was first to discover that a single photon has multiple states and thus can hold and transmit multiple bits of information.

It is now hard to imagine a new major improvement in information recording. Could there be something providing bits different from the multiple bits per photon which in effect provides more information? The main challenge now is how to understand and make useful the huge amount of information that is constantly accumulating. The doubling constant from the WEBB telescope must be very short! Who is available to study it all?

28.2 Bell Labs – AT&T

While at Princeton time was also spent at Bell Labs in Murray Hill. Several other Princeton staff made use of the same arrangement. Specifically, John Tukey had a continuing arrangement to share his time between Bell Labs and Princeton. In my case this started with occasional visits for meetings or seminars but then evolved into a more formal arrangement and finally in 1968 I agreed to work full-time at Bell labs and resigned from Princeton. This was at the point that, due to the obligatory retirement at age 65, Morgenstern also retired from Princeton. He then moved to a Professorship at NYU to their substantial benefit and Princeton's loss.

While at the Labs I learned about important work related to my interests. One development was that conducted by George Stibitz. Stibitz demonstrated for the first time the process of remote computing by comunicating data between Dartmouth's campus in Hanover and his computer in New York City (Bell Labs was then still located in New York city) via teletype equipment during a meeting of the American Mathematical Society. Stibitz subsequently joined Dartmouth in 1964 as a research associate in the Physiology Department. He became a professor in 1966 and worked primarily on physics, mathematics and computer applications and their connection to biophysical systems. He was awarded an honorary Doctor of Science degree in 1986. A large plaque commemorating the 1940 computer demonstration hangs outside the door of McNutt Hall. See his entry on the Dartmouth web page: George Stibitz.

28.3 Beginning of New Work at Bell Labs and AT&T

First, it should be mentioned that this work was done under extreme secrecy. AT&T was concerned that this work could be misunderstood while it was underway. However, finally and after the work had been completed and despite our efforts, divestiture was forced on AT&T, Bob Breedlove was allowed to publish a full report of the work. I helped with the book and Bob generously named me as the joint author.

See An Incremental Cost Model of MTS Traffic, 2022 (11) or on my Internet Archive Library page at An Incremental Cost Model of MTS Traffic..

From before starting work at AT&T in New York it had been clear to me that IBM was opposed to AT&T's interests. This was not understood within AT&T. For many years starting sometime before the WW2 period the IBM and AT&T Boards of Directors had held regular, but highly secret, meetings. What IBM chose to do was in conflict with what they said to the AT&T Board at the meetings. IBM represented that the had shared interests with IBM restricting its relevant activities to the computer market while AT&T would be free to continue its communications business. As appropriate, they would share activities.

This was made clear in the case of AT&T transferring all of Stibitz's lab to the IBM labs in Yorktown. The was done late at night on a weekend. And, of course, this was the reason that Stibitz left for Dartmouth.

I mentioned the misunderstanding between AT&T and IBM's clear intentions to Charlie Brown but he was not convinced. After the ruling in IBM's favor and the consequential breakup of AT&T he came to me and said that he was sorry that he had not accepted my information. Only speculation can indicate how communications and computing would have developed if a decision more favorable to AT&T had been reached.

Another useful action during this period was a conversation with Bob Santos, Vice President of Information Management at AT&T. I pointed out that AT&T had on lease (IBM then did not sell computers) over 10% of IBM's installed base. But, since nearly all AT&T computing facilities were from IBM, IBM had the potential of threatening to withdraw their equipment in case of conflict. This gave rise to Santos enforcing a two vendor policy for all major centers. IBM was not pleased.

28.3.1 AT&T New Technology: The ESS1 Switch

Incidentally at about this time AT&T had developed the ESS1 electronic telephone local office switch which was to replace the electromechanical stepper switches throughout the Bell system.

The purpose in mentioning this is to show the extents to which AT%T would go to avoid implementing something could be viewed as a stored program computer.

The definition of "computer" that was used was a system which could modify its own memory. Thus, the ESS1 had read-only memory. In order to change a memory module it was necessary to remove it from the switch, transport it to a separate write station, write the new data and then return it to the ESS1 system. Obviously, this was time-consuming. The first installed ESS1 was in Trenton, NJ in 1965. And, New Jersey Bell chose to widely advertise the planned cutover. The cutover took place late at night and involved the transfer of all the individual telephone lines from the current switch.

Since, there had been wide publicity of this event many people early in the morning picked up their phones in order to try the new system. Quite shortly the system was overloaded and crashed. The only choice was to rewire the old switch.

ESS1 was modified and extended in order to make it more flexible and closer to a conventional computer. A significant number of the improved 1AESS systems were deployed. Eventually ESS4 with a more conventional computer design was implemented and replaced the higher level Tandem switches.

At about this time IBM, through a blind entity, had purchased one of the local independent telephone companies in order to learn the business. This was not known to AT&T until much later.

28.3.2 Computing at Bell Telephone Labs, Murray Hill

When I started more substantial work at BTL I found that the GE 645 computers were unworkable for the tasks that I needed to complete. The promise by the computer group that the 645 running MULTICS would work "soon" was not accurate. So the machine had to operate in 635 mode and therefore no paging. This also was not reliable.

Bill Baker called on me and asked if I agreed that the computer

group should be fired. I said that while they had failed in all respects it probably would not do more harm to let them continue with other tasks. This, sadly, resulted in promoting the C language and UNIX. An indication of their attitude toward practical computer systems development was shown when someone asked Kernigan what a particular line of C code would actually compute. The answer was "ask the compiler".

For my own work which required reading a large number of magnetic tapes which contained data concerning the operation of the MTS system I found that the jobs had to be submitted to be run at night since they prevented other jobs from running during the busy daytime. I found that typically in the morning the job had failed, but a different failure each night. So, I came in to watch what was happening. Consistently the job would run for some time reading in data from a tape. But then the tape drive would signal an error, the tape would be rewound and re-positioned and the read retried. And, this always appeared to succeed, but then the program would encounter an error. After a few checks the problem became obvious. The error recovery code contained an error such that the tape block containing the original error was not reread. The recovery was off by one and the block following the error block was read instead. This meant that an incorrect number of blocks was read even though the "recovery" seemed to succeed.

This became the point at which the labs gave up on GE and Multics. Richard Hamming was right: he said after the committee he was on recommended GE as the supplier: "Buying a computer from GE is like buying a toaster from IBM". Also, I visited MIT to find out how the MULTICS development was proceeding. There I discovered that there were a number of essential object modules for which the source code had been "lost". And, typically, there was no formal definition of the function of each module. This could not lead to a reliable system.

I moved my work to a UNIVAC 1108 system at Bell Labs at Whippany which proved to be reliable. It had the added advantage that its time-sharing remote access worked well for my kind of work. Thus it was only rarely necessary to visit the site. And, since batch jobs and interactive jobs had exactly the same syntax it was very easy to switch between the modes and all done remotely.

28.4 Continuing Work at AT&T shared with Imperial College

While continuing work at AT&T I was offered a position at Imperial College. I was appointed the Reader in Statistics under David Cox. It

was agreed between David and Martin Wilk that my time would be shared between AT&t and Imperial. In those days the Summers were pretty much free of College responsibilities. Thus, I had the opportunity to spend time at AT&T in New York. We had a home in London, but also sublet an apartment in New York. This technically satisfied the rule imposed by the Consent Decree that AT&T only conduct business within the US. Still, AT&T was sensitive about this and I was sometimes informally described as the million and one'th employee.

There was some concern about paying the costs which were connected with my AT&T work, particularly my UK telephone bill. In the UK BT only sent bills every quarter and these were based on a meter reading. Of course the meter only registered a fixed number of digits. When it reached the maximum number the meter rolled over and started again at zero. If it was noticed when it came time to read the meter that the current meter reading was less than the reading for the previous period it was assumed that the meter had "rolled over once" and the maximum number of units was added to the current reading. This did not take into account that the meter may have overflowed more than once. This was frequently the case for me. It was hard to explain this to AT&T accounting! However, since I mainly used the phone line for online interactive computing connected to the computer at 195 Broadway I could approximately account for the time spent on AT&T work from the AT&T computer accounting data and this was accepted.

Initially calls to the US were operator handled by the UK international operators. A problem with this was that the operators initially assumed that the carrier tone (a high squeal) was an error. I had to explain carefully that I really wanted that tone! After some time I mentioned this at AT&T and they chose to implement direct dialing between London and New York. This was, incidentally, the first international interactive computing. I used quite a lot of time and got a lot of work done. Even the occasional line drops were only a minor problem since the computer was well enough organized to allow resumption working at the point where the connection dropped.

Finally, when I asked a senior person at BT research about dialing from London into a computer in New York I was assured that this was impossible.

28.5 Bell Labs – AT&T Full-time

While I was still at Princeton and part-time work at Bell Labs Martin Wilk encouraged me to join Bell Labs at Murray Hill on a full time basis.

However by this time it was also clear to me that IBM was opposed to AT&T's interests. And, that they were devoting substantial efforts through CBEMA and other channels to ensure that the CBEMA view would prevail. As mentioned before, this was in conflict with what they said to the AT&T Board in the periodic, but highly secret, joint meetings of the boards (at a remote location in rural Connecticut).

I mentioned this to Charlie Brown but he was not convinced. Immediately after the ruling in IBM's favor and the consequential breakup of AT&T he came to me and said that he was deeply sorry that he had not taken my advice.

Only speculation could indicate how communications would have developed if a decision more favorable to AT&T had been reached. Certainly better than what has happened.

I refused to join with CBEMA. It was clearly in all of the CBEMA members interests to oppose IBM. But somehow IBM convinced them to join in opposing AT&T

And, even more directly it was in the CBEMA members interests to support AT&T in order to reduce the dominance of IBM.

28.5.1 Analysis for FCC compliance and Corporate Planning – The Message Toll-traffic System

My work at Bell Labs increasingly concerned the analysis of the operation of AT&T, the parent company of Bell Labs, and at that time still the monopoly provider of communication services for the US, and was the world's largest corporation. (And prior to the 1956 Consent Decree AT&T also provided similar services in other countries.)

This work was centered at AT&T Corporate headquarters at 195 Broadway. The two people who initiated the effort were Robert Breedlove and Martin Wilk with support from John Tukey. They enlisted me to provide technical skills, knowledge of relevant economics and statistics and computation.

One aspect of this work was the organization of an email system. This was particularly useful since I was part of the time resident in London at Imperial College. I setup the email system within the filesystem of our computer. Each file within the email directory had a name showing the person from and person to for the message and, of course, the time and date of the message.

During this time the issue of *PicturePhone* came up. Bell labs at Holmdel had developed a system which allowed live image transmission over the phone network. This was promoted as a candidate for widespread use. (A good summary of videotelephony is at: videotelephony. I received a phone call saying that an important meeting about offering PicturePhone was to be held at 195 Broadway. I said could we not handle this through PicturePhone, but I was told that this was not appropriate as the meeting was bf very important!

In order to carry out this work on a more full-time basis I joined a an AT&T headquarters group at 195 Broadway, New York. The basic purpose of this work was to determine in detail the long-run costs of providing AT&T message toll telephone services. An analytic model which accurately provided this information would permit efficient capital planning and would satisfy the FCC legal requirements with respect to the permitted rate of return on AT&T assets and fair treatment (no cross-subsidies) to all customers. We completed this analysis and produced the computer programs and data flow so that the FCC requirements were accurately met and the capital planning by AT&T met the projected demand requirements. This transformed the relationship between AT&T and the FCC from an adversarial one to full cooperation. The details of this work have been published as: *An Incremental Cost Model of MTS Traffic*, 1975 (11). At the time of this work it was described as the largest data analysis effort ever undertaken. The important result was that it consistently produced highly accurate results. At each time period the previous estimates matched the actual measured costs and quality of service. Thus, the intended rate of return was achieved. This was only made possible by the meticulous recording of installed equipment, details of traffic, and costs throughout the Bell System.

During this time there was a surprising exchange with one of my staff. They mentioned that a one percent error in our analysis would cost about one million dollars. I looked surprised, but they added: "that would be one million a day".

28.5.2 Completion of FCC compliance and Corporate Planning Analysis

The Justice Department lawsuit was settled in 1982. The result was the splitting up the company and this was completed by 1984. This event is usually described inaccurately. (See for example the Encyclopedia entry at: AT&T divestiture.)

Three incorrectly understood issues adversely affected the outcome:

1. From about 1972 until the divestiture of AT&T in January 1992 AT&T and the FCC cooperated fully in the rate determination process. This extended to the fact that in 1990 the FCC was given the AT&T computer system programs and data so that they could, using their own computer, replicate the AT&T results, or to try their own rate proposals.
2. The main instigator of the antitrust lawsuit was IBM. IBM was careful to conceal their motives and this including making false representations to AT&T. It was IBM who convinced CBEMA (Computer and Business Equipment Manufacturers Association), renamed to the Information Technology Industry Council (ITI) in 1994) to join with them in the lawsuit. IBM publicly acted as if CBEMA had independently initiated the lawsuit.
3. This was not understood by AT&T senior management even though I tried to warn them. The day after the divestiture decision Charlie Brown came to me and said that he was sorry that he had not listened to me. Of course, I wish that I could have done more.

After the divestiture the analysis system as developed for the FCC was transferred to the then separated AT&T Long Lines Division for their facilities planning.

However, a useful event during this period was a conversation with Bob Santos, Vice President of Information Management at AT&T. I pointed out that AT&T had on lease (IBM then only leased computers) over 10% of IBM's installed base. But, since nearly all AT&T operational computing facilities were exclusively from IBM, IBM had the potential of threatening to withdraw their equipment for any reason. This resulted in Santos issuing a directive to implement a "two vendor policy" for all major data centers within the Bell System. IBM was not pleased. But, it provided AT&T protection from unreasonable pressure by IBM. The main vendors for the second system were Burroughs and Sperry UNIVAC. Obviously, I was seen as being anti IBM. But when a

question came up at the Piscataway data Center, where the dividend checks were printed (under extreme security!!) someone suggested moving that work to an alternate vendor. I made very clear that only IBM was capable of sufficiently reliable printing! The IBM machines which were when doing the printing did absolutely nothing else, were under armed guard, and did the task quite well.

In another conversation with Santos the field trial of a UNIX-based system was discussed. The system, written at Murray Hill using the UNIX operating system, was intended to support Information Operators responding to customer questions. The system was claimed to be ready for use. It was installed at a call center in Southern Bell and went through tests and operator training. It then went live, but after about an hour it crashed and could not be restarted. There were no known hardware problems. Santos issued a memo stating that no UNIX-based systems would be used for operating purposes within the Bell systems. This ruling lasted until the divestiture of AT&T.

28.5.3 AT&T Employee and Customer Policies

During my time with AT&T I found out a number of facts about their handling of employee and customer relations.

In my experience AT&T was the only commercial organization which maintained a dedicated effort to act in their employees' best interests. This, of course could be considered as, and was, paternalistic. But, it did provide an environment in which the employees felt comfortable and were well cared for.

All new employees started with an extensive training program which included learning how to climb up a telephone pole in order to make repairs.

And, the staff who interacted with customers were especially trained to be courteous and accommodating. Of course, records were kept of the customer interactions so that if the behavior was dishonest or in other ways inappropriate more senior staff would take over. This included cases such that the customer claimed that they had not made a billed toll call. If even the itemized call record showed that the call was made, the charge would be removed. But, each event was logged so that if this behavior became obviously inappropriate further action could be taken. An extreme case of this kind was the people in New York taking bets on the horse races in New Jersey. They would hold the phone connection to spotters at the track open continuously so that

there essentially never was a call termination.

There was a long and entertaining period of people trying to trick the system. AT&T took a moderate view of this and only intervened when the events caused serious problems.

The most troublesome event of this kind came about because the routing codes for toll calls were published in an issue of the Bell System Technical Journal. The issue was withdrawn but too late. Therefore anyone with the skills could route a call to anywhere by any route. A standard challenge was who could create a call back to a phone next to themselves but which crossed and recrossed the continent the most times!

28.6 AT&T Corporate Planning

This was an intense period of work. The purpose was to provide convincing results that showed that AT&T was meeting the requirements of the Consent Decree which was managed by the FCC. This required a full understanding of the long-run incremental costs of providing message toll telephone and related services for the US. The details of this are documented in the publication: *An Incremental Cost Model of MTS Traffic*, 1975 (11).

On an annual basis the relevant data had to be presented to the FCC. Our analysis did accurately describe the long run incremental costs of the providing the AT&T services. The FCC was satisfied with these results and the efficiency of the services were also substantially improved.

And, after a few years the FCC asked if they could perform the same analyses as we had done for each year. This was agreed and the FCC ordered an Identical computer and we supplied all of the analysis software for them to independently verify our results.

Finally, I had a surprise: One of my staff mentioned that a 1% error in our analysis would cost 1 Million dollars. I looked puzzled, but she replied "that is 1 million a day".

29

Consequences of 1977 AT&T Divestiture

The divestiture of AT&T took the form of the breakup of the AT&T Corporation into separate companies which each provided communication services within their geographic boundaries. And a separate company, Long Lines, was created for the handling interstate and traffic crossing separate company boundaries.

The Long Lines Company took over the analysis system that we had developed for the previous AT&T. While they were not under FCC regulation they found the system to beneficial for their planning.

The divestiture was intended to ensure competition. Its effect proved to be increasing costs and degraded services for communication services in all the the regional service areas.

29.1 Closure of Research Labs

However, it also had the consequence that the Bell Labs research facilities were also split up and were assigned to the Company which happened to provide services where they were located.

Thus the research labs including Bell labs at Murray Hill and at Holmdel and others were reassigned to the local operating companies in their areas. These new operating companies had no experience in research and fairly quickly lost interest in paying for a research lab. The labs were sold off and allowed to run down and were closed.

This was a tragic loss to research and to its contribution to welfare. The original Bell Labs provided information theory, the transistor, computers and much else. The closure of these labs was a loss on a world wide scale. IBM felt that it was better that they close all this

activity in order to reduce or prevent competition. There was no real interest in technical research within IBM. Of course, they had a major activity which gathered all technical and financial information from their perceived competitors.

29.1.1 Background on AT&T Divestiture

By now if seems appropriate to discuss this history. Previously I have only mentioned a few aspects of this in talks about technical matters (which is what I do).

So, very briefly, the key fact that was kept secret in these maters was the role of IBM. Until the divestiture the AT&T and IBM Boards met regularly, in utmost secrecy to discuss matters of mutual interest. AT&T was, as it turned out, naively trusting about this. I stopped work at AT&T (and Bell Labs) substantially before the divestiture agreement and it was then that IBM approached me hoping that I would act on their behalf. The Congressional hearings called "Computer Inquiry II" were in fact instigated and managed by IBM (without AT&T's direct knowledge). It was IBM's intention to prevent AT&T from doing any business other than analog voice communication. They succeeded in convincing the investigation to agree that digitizing a voice signal as part of the transmission constituted computing and therefore was not allowed to AT&T under the Consent Decree. Only after it was too late did AT&T accept the evidence that IBM was acting against their interests, and by then the Consent Decree was the only available choice.

During the second Congressional and Justice Department investigations there could have been legitimate discussion about whether AT&T was abusing its monopoly powers. Since the process was managed by IBM, this discussion never really took place. So, whether or not AT&T should have been restrained or broken up, the decision was taken for what seem entirely wrong reasons. At the time of the divestiture most people (but not me) felt that this was the right decision whether or not it was done for the right reasons. Now, many people seem willing to reconsider. The current state of mobile phone and Internet communications is not quite ideal and standard mobile voice services are at best variable.

Without the intervention of IBM a result of the introduction of modern mobile phones could have been much better introduced than what has happened. A modernized version would surely have resulted in "everyone is entitled to phone access" on fair and economical terms for mobile service for the entire US.

This does indicate that the regulation of business enterprise for the social good is a complex subject. It has at least two fundamental difficulties: First is the Arrow Theorem which shows that there is no solution which is "best" for all parties. Second is the problem of non-additivity as pointed out in von Neumann and Morgenstern. This, as is well known, means that there is no "right" answer. From my perspective (I went from LSE to Princeton and worked with Oskar Morgenstern) Game Theory is helpful in trying to understand the possible outcomes of such conflicts between multiple players and coalitions. Alarmingly, in this specific case, IBM was able to put together a coalition of all the major computer companies to act against AT&T even though this was clearly against the interests of all of the other computer companies. Conventional economic theories have trouble explaining this behavior.

29.2 IBM's destruction of Research Laboratories

Thus, not only did IBM destroy AT&T, it also destroyed all of the Research Labs in the US and elsewhere. This has been a catastrophe. Others have recognized this destruction, such as Thomas F. Rosenbaum, President of Caltech.

I am sure that this is more than you asked for, but as you can see, I think this was an important series of events. The lessons that should have been learned from it have not been learned. So, next time...

More recently, a study has been published by the Justice Department under the title: "The AT&T Divestiture: Was It Necessary? Was It A Success?". It can be found at: Antitrust Division, U.S. Department of Justice The author is Robert W. Crandall, The Brookings Institution, U.S. Department of Justice, March 28, 2007.

30

Sperry UNIVAC

After the AT&T work was concluded in 1977 I joined Sperry Univac.

I joined on the basis that I would provide advice to the President and would participate in the introduction of new technologies and techniques. Subsequently, I agreed to take on the role of Director of Research and held that responsibility until the company merged with Burroughs in 1986.

30.1 Two initial responsibilities

1. Review of key issues with CEO Gerald Probst. The first of these concerned the approval of a plan to produce a new computer series which, it was argued, would respond to the IBM 360 Series. The planned series would be made up of systems capable of a new mode and an emulation mode of the current systems. This implied that while operating in any one of the modes the system would be inefficient as compared to a dedicated single mode system. In addition, customers were to be convinced to convert to the new mode. Detailed analysis showed that there were practically no potential customers who would find this cost-effective for their specific needs. I presented this to Probst and the new series was canceled and replaced by the further development of the 1100 Series which has proven to be successful to this day. During all the time that I was at Univac I met Probst frequently, most often at the company canteen early in the morning. We would sit with whoever happened to be there and discuss any topic that came up. All of this, to me, showed exceptional good sense.

2. Participate in Probst's *customer satisfaction list.* This, was for the most part, a fun part of my work. Probst was, exceptionally, di-

rectly concerned with how his customers were succeeding with their computing needs. The *Customer Satisfaction List* contained a range of customers chosen by Probst, often but not always, due to some problems that were preventing them from achieving their computing goals. My role was to offer advice and, if necessary, determine what was causing the failures and recommend, or sometimes implement, effective solutions. This often meant travel to nice places, accompanied by my wife, of course.

It was Bill Raymond, who worked on Probst's staff, who managed the handling of the *customer satisfaction List.* He was extremely effective in identifying problems and managing the resources needed for resolution. He and I worked well together. I figured out what actually had gone wrong and he would obtain all the equipment and resources needed to fix it![1]

[1] Of course, keeping in mind the principle: if it is not broken, do not fix it.

30.1.1 SNCF, Paris

As an example case, the systems installed at SNCF (Société Nationale des Chemins de fer Français) in Paris were causing serious delays.[2]

[2] Work to do in Paris accompanied by Ilse.

A key function of this system was to schedule all of the train traffic in and out of Paris. Most important was the arrival of goods trains early in the morning for onward delivery of produce to very many stores throughout Paris. After repeated unsuccessful attempts at establishing constant system availability, the SNCF management demanded "a non-French speaking expert" to be provided to resolve the problems. By this they the meant someone from UNIVAC in the US. I agreed to take on the task. However, I had to point out that I spoke French, if only with a Swiss dialect. So, Bill Raymond arranged for my wife and I to travel to Paris for an extended stay. When I was introduced to the Grand École educated staff at SNCF they immediately made remarks in French such as "how can this senior person know anything about the technical issues that we are facing?" I smiled pleasantly but also during the evening went down into the computer hall. This was a large room in the basement of what had been a railway station. I noticed two things:

1. There were very many subsystem models supporting many differing devices on the channels, thus greatly complicating the maintenance and support requirements, and
2. The night shift operators were permitted (actually their Union de-

manded) that they could cook their steaks in an open broiler each evening in the computer room. When unnoticed, I removed a filter from one of the cabinets. This needed care as it was dripping with oil.

On the next day I asked that I would like to explain what needs to be done. This came as a surprise as no one knew of my visit to the computer hall. But, they called a meeting. At the meeting I started in French apologizing for my Swiss patois accent (which, of course, I had learned as a child in Montreux (See Section 9.1). Then I switched back to English, hoping that my accent would not cause misunderstanding. I then reported that the one outstanding software system error had been identified and corrected. The error only occurred if several different device types were connected on the same channel in an almost never used manner. The error was due to a timing window which had been overlooked.

In any case, Raymond had ordered replacement subsystems to very much reduce the complexity and improve the performance of the system. These arrived in about ten days and there were no more faults for an extended period.

Early in my visit I was asked to go to lunch with the staff group. I said: not until the system is fully repaired and no further errors have occurred.

When that had been accomplished I agreed to go to lunch with the senior technical staff. That was fun and, of course, it lasted to a time such that returning to work was obviously not convenient.

We stayed on to ensure that no new problems arose. We had a particularly enjoyable several weeks in Paris! And then off to Zurich.

30.1.2 Union Bank, Zurich

This trip to Zurich was just in order to review the Union Bank operations. Their Univac system was working quite successfully but they found that after it operated continuously for over a year without any restart some anomalies appeared in the system's internal accounting data. The cause of this was that some accounting numbers based on events since the last system restart were stored as 36bit integers. After a long enough time without a system restart they overflowed and the count restarted from zero. To repair this all counts were converted to list structures so that they could count "forever".

30.1.3 Responsibility for UNIVAC Research Division

There was concern about the Research Division and the current head, who had used it as a part of marketing, had left. I was asked to take responsibility.

This was a challenge. The division was composed of over 100 scientific and engineering staff some of whom had been members of the original Eckert-Mauchly Computer Company. So, a lot was known of details of the original EDVAC computer built at the Moore School. Thus, they had a very useful perspective as well as a high level of technical skill. However, for some time they had been sidelined for various reasons including the fact that they were located in Pennsylvania but the Company development center was in Roseville, Minnesota. In addition, the organization had become overly bureaucratic: I found that there were more "managers" than there were working technical staff. My first action was to explain, at a meeting of all the staff, that the position of "manager" was to be eliminated.[3] We would define projects and organize project teams with well-defined technical goals. Team members would report on progress as significant goals were completed. The projects would be defined in consultation with the development groups and with outside people in the research community. Typically, both outside research people, for instance from the University of Pennsylvania and Caltech, as well as development staff would also participate in each project. And, staff would participate in University research as seemed useful. In any case, I kept in contact with the staff by "walking around." And, I helped on projects if it appeared that I could be useful.

[3] Goodbye to Managers.

I offered to help to find alternative employment in the Company for all managers who preferred not to get back to technical work.

30.2 New Projects

The projects that were newly initiated and joined in involved VLSI circuit design, secure system architecture, reliable operation and precise fault management and recovery of the computer systems and implementation of paging-based and virtual machine systems in all of the Companies' products.

UNIVAC had not, since the Echert-Mauchley days been closely connected with research in fields related to computing systems. To change this I initiated a student participation in research activities with stu-

dents from the nearby University of Pennsylvania. And, established a more extensive collaboration with Carver Mead's VLSI Systems Lab at Caltech. This involved financial support and longer-term participation by senior engineers from the UNIVAC research and development labs. A result of this collaboration was the implementation the most technically advanced and highly cost-effective computing systems. A confirmation of these results was that IBM also took on the same design techniques and implementation for their new systems.

For an extended period there had been a very productive interaction with Herb Callen at the University of Pennsylvania. He was the author of the widely used text on thermodynamics(12).

30.2.1 IBM License Request

IBM offered to acquire a license for the niobium-based superconducting device technology being developed in our lab. UNIVAC management would not allow me to pursue this even though I made clear that this technology would not be of value, but that IBM was willing to offer several million dollars for the license. It also appeared not to matter that I pointed out that IBM would use our results whether they paid anything or not.

30.2.2 Key contributors to the Unisys (UNIVAC) Operating System

I found that Univac, as it was then named, was quite unique among software development centers. Jerry Boss had overall authority for the design and coding of the system kernel. And, the software system was based on a compact kernel which was only accessible through a protected hardware gate instruction (called an ER for Executive Return).

Boss enforced the kernel coding rules VERY strictly.

And, there were at most about 8 programmers. And, one of these, Derrick Zave wrote most of the code. He went on to work with Knuth at Stanford.

There were strict coding rules:

1. All code elements had to be signed and dated by the author.
2. There was a strict format which supported processing by a program which produced flowcharts from the code. However, the Flowcoder

processing was not done as completely as originally intended even though the formatting was widely used. This format also provided full description of the purpose of the code, its inputs and outputs, and the author.

The most productive programmer by far was Derrick Zave. He was one of the small number of programmers who wrote nearly all of the system kernel code. He wrote by far the most and best code.

After he had contributed much of the core kernel code he noticed the need for a "meta-assembler" which could compile any defined input language and output code for any other defined language or hardware instruction set. This system, MASM, became the core of all of the programming in the system development center. It was not only the assembler for the mainframe systems, but also for the various sub-sytems which often used various micro processors from Intel or Motorola.

I visited the Roseville Development center quite often and always went first to talk with Derrick. One evening I stopped by and asked how his meta-assembler was coming along. He said "actually I am having a lot of trouble with the efficiency of a commonly used function". I answered, naively, "but you must have quite a lot of code done".

His answer was simple: I have not started to write any code yet!

Subsequently when times were changing I helped that Zave could move to Stanford and work with Donald Knuth. They had comparable skills and interests.

30.2.3 Closure of the Research Group

The Burroughs merger with Sperry Univac ended my opportunity to work effectively in the new organization. Obviously, I was a member of the group that opposed the merger and in any case Probst left for a new job in the Sperry Corporation.

However, remarkably, the resulting company, UNISYS, provides systems based on our “provably correct” design methodology. This methodology is also apparently used by IBM in their continuing mainframe systems business. The technical people from UNIVAC have also succeeded in carrying out substantial product improvements including, most importantly, paging and including the full virtual machine implementation. The new systems are still selling to customers who require

fully correct operation of their systems, such as some banks.

Both UNISYS and IBM mainframe organization have used the reliability technology that we developed. As far as I know, IBM has not implemented the virtual machine nor paging structures.

30.2.4 Study of Reliability

There have been few serious study's of reliability in electronic systems, but we made use of the work of Jeffrey Alun Jones as reported in his PhD thesis: "Electronic Reliability Prediction: A Study over 25 Years..", University of Warwick, Department of Engineering, December 2008. (I do not have a stable reference for this thesis, but it must exist at Warwick.)

30.3 Howard Resnikoff

During this period I formed a close relationship with Howard Resnikoff. He had held faculty positions at Rice, UC Irvine, and Harvard. He also founded Aware Inc. I worked with him on an informal basis over many years. In particular helping with the development of wavelet transform signal processing VLSI circuits. An important outlet for this work was Analog Devices. They took up licenses and use our designs in their communications products, specifically ADSL modem circuits. These designs also became widely used in medical imaging systems. So, it was good to be able to help with this.

31

The Thatcher/Reagan Years

It is painful to reflect on the period in the UK from 1979 to 1990 when Margaret Thatcher was the UK Prime Minister. Thatcher did serious damage to the UK Universities by drastically reducing their funding. She also reduced or canceled research wherever she could find it.

However, she also demanded that the homeless pay their poll tax. Of course, the homeless did not pay nor did many others. We also chose not to pay.

31.1 The downfall of the Soviet Union

Starting in 1991 the Soviet Union was in disarray. It would appear that much could have been gained if a plan similar to the Marshal Plan had been offered to Russia at the time of the collapse of the Soviet union.

Instead, Reagan, apparently convinced by his wife and by Milton Friedman, decided that addiction to unbridled and lawless free enterprise, provided the only "profitable" social and economic organization. Thus this was the choice offered for the reconstitution of Russian society. This led to the inevitable destruction of any reasonable social, economic, or political structure. We all are paying for this now and far into the future.

A substantial group of oligarchs, many now resident in Austria, owe their extreme wealth and "freedom" to Friedman, as does Putin.

31.2 *How Freedman economics works*

As an aside Friedman was interviewed in his luxurious San Francisco apartment by a New Yorker writer who asked "why are there so many people sleeping rough in the streets and parks?" Friedman answered: "It is obvious: this is what they prefer".

31.3 *Decline in Research*

The events of the 1980's also gave rise to a loss of research capability on a wide scale. The divestiture of AT&T required the breakup and closing of all the AT&T research labs.

It was IBM that forced the closure of the AT&T labs and this led to the closure of nearly all of the industrial research labs in the US and also in Europe. IBM thought that this was to their advantage but this has not proved to be the case.

The era of a vibrant and productive research community supported by Universities, industry, and government agencies such as ONR has been seriously curtailed. The view of Watson Jr. at IBM was made clear at Section 15.8 where the meeting of Watson and Kilburn is described.

Very sadly the latest disregard of research by the US Government is leading to a further loss of human progress. The loss is most pronounced in the US. But this research was in its time a quite important contribution.

32

Employment Summary

32.1 Choice of Employment

My "serious" employment started in 1955.

Up to this time and continuing to the present I never applied for a job nor asked for any specific payment. If asked, I always said that I would accept what seemed fair.

32.2 Employment Summary

It seems appropriate to summarize my formal employment as of about 2023.

EMPLOYMENT

- 1955-57: Research Assistant in Solid State Physics at Caltech.
- 1957-59: Research Assistant (1957-58), then Research Engineer at Consolidated Electrodynamics Corp., Pasadena, California.
- 1959-62: Consultant to Consolidated Electrodynamics Corp., and Director, Consolidated Electrodynamics (U.K.) Ltd.
- 1959-62: Technical Consultant for several British and American firms including Shell and BP.
- 1963-68: Research Associate, Econometric Research Program, Princeton University, Princeton, New Jersey.

- 1964-66: Assistant Professor, Economics Department, Princeton University.
- 1966, 69, 76: Visiting Professor, Institute for Advanced Studies, Vienna, Austria.
- 1966-68: Assistant Professor, Statistics Department, Princeton University.
- 1967-68: Continuing Consultant, Bell Telephone Laboratories, Murray Hill, New Jersey.
- 1968-69: Member of Technical Staff, Bell Telephone Laboratories (BTL).
- 1969-70: Lecturer, Department of Mathematics, Imperial College of Science and Technology, University of London, London, England.
- 1969-77: Continuing Consultant to Management Sciences Department and Corporate Planning Organization, American Telephone and Telegraph Co., New York, New York.
- 1970-77: Reader in Statistics, Department of Mathematics, Imperial College of Science and Technology, University of London.
- 1972-77: Continuing Consultant to Wirtschafts und Sozialwissenschaftliches Rechenzentrum, Vienna, Austria.
- 1977-80: Senior Professional Consultant, Sperry Univac, Blue Bell, Pennsylvania.
- 1980-81: Visiting Fellow, Princeton University, Princeton, New Jersey.
- 1980-83: Director of Research, Sperry Univac, Blue Bell, Pennsylvania.
- 1982-88: Consultant to Systems Development Foundation, Palo Alto, CA. See SDF entry on Online Archive of California (OAC)
- 1983-87: Head of Research, ICL, London.
- 1985-87: Visiting Professor, Department of Computation, University of Manchester, Institute of Science and Technology.
- 1986-87: Founder and acting Director of Research and Engineering, Active Memory Technology, Ltd.
- 1986-92: Schlumberger Professor, Imperial College of Science and Technology, University of London.
- 1988-92: Research Fellow, Aware Inc., Cambridge, MA, USA.

- 1989-93: Visiting Professor, Information Systems Lab, Electrical Engineering and Statistics, Stanford University.
- 1993-2010 : Consulting Professor, Information Systems Lab, Electrical Engineering, Stanford University.
- 1998-2003: Founder and President *Pixel Devices International Inc.* Sunnyvale, CA. (Company acquired by Agilent Technologies, February 2003.)
- 2003- : Visiting Faculty, Institute for Neuroinformatics (INI), ETH Zürich.
- 2010-2017: Research Affiliate, Statistics Department, Stanford University.

For the future I plan to just pursue interests not currently being addressed but that seem most challenging, interesting, and useful.

33

Introduction of Personal Computers (PCs)

This started a dramatic change in the role of computers. It is, and will continue to be, tragic in its consequences.

33.1 The Introduction of DOS

On 12 August, 1981, Bill Gates convinced an IBM executive, James Cannavino, to agree a license for software which ran on an IBM specified PC (Personal Computer). The software was named (MSDOS) (Micro Soft Disk Operating System). This agreement was signed at IBM Boca Raton.

The lease of the software which Gates had "borrowed" gave rise to a new age in computing. The Microsoft software running on an IBM architecture PC based on an Intel architecture CPU came to dominate much of the commodity and desktop personal and business computing activity.

33.2 DOS "features"

Since there was no documentation the program just "did what it did". This has continued to lead to serious errors. For example, during the recent COVID in the UK many thousand patient records were lost due to the fact that the MS spreadsheet being used simply dropped all entries after 64 thousand. No copies of the lost records were available.

The problems with this system code included:

1. The code was entirely assembly code. (This was standard in those

days.)

2. No documentation nor test sequences.

3. No error checking nor handling.

So, the code just "did what it did."

33.3 1980's and the MS PC

Cannavino acting on his own accepted that IBM would agree a license for the software. IBM had never agreed a license for anything. But, since this was not viewed as of any importance the agreement was allowed to stand. This led to the catastrophic success for Gates and confusion at IBM.

Too late, when Arduino took over IBM and had reviewed the state of the Company he was asked what was IBM's strategy. He answered "We do not have time for that kind of thing, we need to find out how to make money." Immediately after that he appointed Cannavino as head of strategy. But, too late. A consequence of this has been the pervasive use of PC's using Microsoft software.

There was also a Microsoft product named OS/2, but it was based on a totally different and inferior design, based on segments, as promoted by Kernighan and Plauger in their UNIX system. This was instead of use of paging as implemented in the IBM OS/2 and as it has become a necessary feature of practically all general purpose systems. Paging, of course, was developed by the Manchester University group. Paging paging Manchester University

I spoke with a key Microsoft OS/2 developer and mentioned the idea of paging. He said that he had heard of it and might look into it someday!

33.3.1 Consequences of Gates dictated PC computers

There are fundamental problems which make Microsoft PC's unreliable:

1. The hardware required is unreliable since Gates demanded that memory error checking be removed. He personally went to Intel and told them that if the provided memories with error detection

he would cancel all of their MS licenses. This choice by Gates was due to the fact that memories with error checking cost more and therefore impacted sales of MS PCs.

2. The Microsoft software is unreliable as it has been written by various people, some not in any way connected with Microsoft, and in any case undocumented in the code or elsewhere. During the annual developers meeting at Microsoft it has been standard practice for coders unrelated to Microsoft to insert their own code into the operating system code base.

3. During Gates' time almost none of the programmers at Microsoft were employees. They were hired on contract and fired at any time for any or no reason. This may not be as common now, but Gates did have a habit of walking through the programmers area and just arbitrarily picking a contractor and firing them for immediate dismissal. This, it appears, was intended to improve "discipline." By now (2024) about half of the programmers are still on contract. About 80,000 contract staff work at Microsoft.

4. Gates also insisted that PC hardware was as cheap as possible which included reduced reliability. Most prominently he insisted that Intel remove the parity check from its PC memory chips. He said that failure to do this would result in the cancellation of all of Intel's Microsoft licenses. Intel could have challenged this, but chose not to.

5. Commercial and other customers of MS-based systems find that there are quite frequent unexplained failures. In more demanding conditions, such as hospitals, these failures can have serious and often fatal consequences. An estimate that was reported for the UK NHS put the number of such deaths at about 700 per year.

   If commercial aircraft were as unreliable as Microsoft computers the estimate of deaths per year would would surely be in many thousands of passengers. And, the cost of replacement aircraft would greatly increase passenger costs.

34

Times Change

34.1 Manchester University

Manchester led the world in innovation and production of new technologies until the mid 20th Century. It was later the center of innovation in digital computing systems, but this declined and disappeared due to incompetent politicians and inheritors of ownership of the key companies. This led to the collapse of manufacturing infrastructure. This despite the fact that the bulk of modern computer design and implementation was invented at Manchester University. Specifically, Manchester invented the computer memory management technology called "paging". The structure called "paging" is based on the organization of fixed size units of memory. Each unit may be actually in memory or held on a disk. When the memory address is needed in the computer memory it is read from its place on external storage, usually a disk.

It took many years before the same technology was finally implemented in the US. I helped with the introduction.

I was involved in this from the time when at Imperial College. And also as a Visiting Professor at Manchester.

Later when at a key point I was Director of Research at Sperry UNIVAC I helped to introduce an additional collaboration with Manchester University. This provided additional equipment and staff support. This also resulted in substantial benefits to UNIVAC and the Manchester University group.

The most prominent benefit to UNIVAC was the implementation of paging in the 1100 Series systems. It had been thought for a long time that recovery from an invalid address event was not possible in

the current systems. The problem was that insufficient information was available to permit appropriate recovery. The key lacking information was the exact address and context of the invalid instruction. After discussion with one of the key engineers we discovered a quite simple hardware change enabled recovery. This greatly enhanced system diagnostic and fault recovery for the entire system. Specifically, the fault analysis system (FLIT) could execute programs (including the operating system itself) directly on the hardware but recover all state on a fault and thus much more easily diagnose the error.

This one change which enabled paging was the most important contribution while I was at UNIVAC.

In addition as one of Motorola's biggest customers I had to tell them that they must implement paging capability in the MC68ooxx series of microprocessors, or we would have to switch our purchasing to another vendor. That, and plain good sense led to their implementation of paging capability. This was quite simple as just and additional saving of state was needed for correct recovery.

Paging was then implemented in nearly all hardware systems. Sadly, current software still does not make best effective use of the capability as it was defined and implemented in the Manchester systems implementations.

The MUSS documentation is available on the Internet Archive. Volume 1 is at: MUSS User Manual Vol. 1 See: MUSS User Manual Vol. 1 and subsequent Manuals Vol. 2 and 3 are at the same site. The MU6G Instruction Set Manual is also available at MU6G Instruction Set.

34.2 Silicon Valley

Silicon Valley came about when in 1956, William Shockley left Bell Labs and moved to Mountain View and established the Shockley Semiconductor Laboratory. He recruited a number of key staff including Robert Noyce and Gordon Moore.

34.3 Intel

However, they found Shockley difficult and not in tune with their intentions to build integrated circuits. In order to carry this out they founded Intel. This offended Schockley. Additional founding members

were Andy Grove and Carver Mead who commuted from Caltech. While Carver Mead maintained his role at Caltech he was an integral part of Intel development.

Intel was the clearest leader in the creation of Silicon Valley. Gordon Moore and Andy Grove led the Company through their full careers. This was unlike what happened at Google and what became the tragic "standard" in the Valley.

Andy Grove's book *Physics and Technology of Semiconductor Devices* (22) provided the foundations of the behavior of semiconductors for the entire industry. It continues to be one of the most authoritative descriptions of semiconductor behavior for the implementation of semiconductor devices.

34.4 Google

Google started with dreams of doing good. Prominent efforts to do good were the Google Books and Streets projects.

34.4.1 Google Books

The intent of this was to make the world's print literature as stored in both public and private libraries available to all. And, the execution was exceptionally effective (unlike, for example, the earlier attempt by the British Library to transfer their newspaper archive to microfilm).[1]

[1] After completing the microfilm they destroyed the paper copies and then discovered that much of the microfilm was misrecorded or in any case lost and thus the original information was permanently lost.

Google approached many libraries around the world offering to image their entire collections. They did this by going directly to the stacks without looking at or recording the library indices, if any. Thus, they captured everything that was physically in the library as available to them. In some cases the "rare books" section may have been excluded. In the case of Stanford University they discovered that the library had an essentially complete set of the *Annalen d. Physik* even though the online card catalog showed only 2 volumes. The various volumes were distributed in a number of locations within the library due in part to changes in the official title of the publication or mistaken reading of the title by the person responsible for shelving each new volume. There were many other mismatches between the online card catalog and the actual holdings.

Thus, this project benefited the libraries since they could correct

their cataloging and could make their volumes more accessible to the students and faculty and other "eligible" people.

The mistake in this effort was the lack of proper handling of the copyright issues. In particular Wiley and other publishers made copyright violation complaints. These could have been dealt with in appropriate ways that still permitted access to material that was not under copyright, restriction of access to the volumes of a University library to members of that University, and similar restrictions which would still allow full access to material that was not under copyright restriction. An example of such handling is the Internet Archive which has come to terms with even the most extreme publishers like Wiley and Princeton. (Cambridge Press would not have objected to full availability for all their academic publications.)

34.4.2 Google Streets

Google streets captured much of the populated world by recording all of the streets. This effort continues and provides some of the ability to locate and view much of the world.

34.5 Downfall of Google driven by Eric Schmidt

First, see downfall of Google. When the so-called adults, with Eric Schmidt (the temptation to mispronounce his name is quite strong) as CEO, took over Google (See Google takeover), an early and crucial action was to completely shutdown the Books Project. They did this due to the fact that a number of publishers had attacked Google for copyright violation. In some cases the copyright violation claim was invalid, for instance early volumes of the *Annalen d. Physik* are widely viewed as out of copyright restriction.

However, recent changes in the copyright law have extended the term of protection to be essentially infinite (formally at least 100 years). This has been driven by the entertainment industry. It is not appropriate for scientific works, but at present there is no separate copyright for such works.

In any case Google could have retained all of the material but restricting access to material which was definitely under copyright restriction. This would have been of low cost, simple, and still extremely beneficial.

The choices that the Internet Archive have made would have worked for Google as well. See the Internet Archive's choices at: The Internet Archive.

Sadly, for the modern day robber barons, benefit to society was not a consideration. The technical term is *blind greed.* They have not even endowed a university as Leyland Stanford did with a part of his riches.

Of course, other libraries, such as the French National Library completed the scanning of the *Annalen d. Physik* as part of scanning the entire holdings. And, they provide free access on the web.

Thus, at least, Wiley's greed has not been fully satisfied. They apparently have not attempted to attack the French National Library for copyright violation.

Another more useful step would have been to provide the index data from the Books project's acquisitions to each Library for their use. This would have been of great value to each of the libraries in improving the accuracy of their own indices.

The main motivation of the "adults", most prominently Eric Schmidt, was to work for an IPO which would make them very rich. This they accomplished at a very high cost to society, for which they cared not at all. Of course, once they had the money they all left.

34.5.1 Intel

Contrast this with the founders and still recently leaders of Intel. Both Gordon Moore and Andy Grove had serious technical knowledge and the clear intent to make contributions of real value. If they had been at Google the result would have been dramatically different and better. For more information they both have informative pages on Wikipedia (Wikipedia)

34.6 The World Wide WEB

This is an odd event. It started with Tim Berners-Lee with some free time at CERN implementing a system which displayed various "interesting" scenes with some information. This evolved into the World Wide Web. It provides the infrastructure for information display on computer screens around the world.

It is useful to note that Berners-Lee gave a key-note speech to the packed London Olympics Stadium in 2012. He emphasized how great it was that everything was free. He did not mention the high-priced tickets to the Stadium and his own very high speaking fee. And, of course, the tight restrictions on TV viewing and even display of pub signs that resembled the Olympics symbol as owned by NBC, the advertisers. Basically a content-free talk, like much of the WEB.

34.7 *Silicon Valley Moves to Asia and the Far East*

A key event occurred in the late 1960's.[2] Since the foundation of the semiconductor industry an informal group was assembled for the purpose of planning the needs of each new generation of semiconductor devices. It was essential that the supporting equipment for each new fabrication capability would be available in a timely manner. Initially, this was not too difficult due to the semiconductor feature sizes as they were in the 1960's. And, the prediction based on Moore's law (34) also helped with the planning. Gordon Moore discussed this scaling issue with Carver Mead who worked out the likely scaling and its limits. See (23) and (32) for these limits. Moore's initial projection only went to 1975. The semiconductor manufacturing equipment suppliers at that time included Applied Materials, and KLA. Major integrated circuit manufacturers assembled their own fabrication facilities. IBM built everything internally.

[2] A lesson from the history of industrial development.

As device features began to reach sub-micron size the supporting equipment requirements became more challenging and product companies tended to outsource fabrication. Thus, supporting companies developed and needed lead-time to develop the equipment needed for the new fabrication plants. And, the costs of the new facilities increased dramatically as extremely accurate and high-performance equipment was required. Thus, a group was formed to provide the road-map for future equipment requirements. This was, of course, initially based in San Jose.

By this time the high and increasing costs of fabrication plants tended to deter expansion in or near Silicon Valley. New facilities were increasingly developed in the Far East. However the equipment suppliers needed to work closely with the fabricators. Therefore they tended to follow the semiconductor fabricators to Taiwan, Korea, and other far East locations including China. Exceptions at present are Applied Materials in Santa Clara and ASML in the Netherlands. Thus, the Semiconductor Members Association (SEMI) which provides manufacturing

standards for the industry is now global with increasing influence from Taiwan and China. The decisions which originally took place in Silicon Valley have of necessity moved to where the major fabricators operate.

34.8 A precursor

This reminded me of Manchester, England, which was the heart of the industrial revolution and led technology into the computer age. The among the earliest, and best computers were invented, designed, and built at Manchester University starting during WW2 and continuing into the 1960's. By the 1980's funding had been very much reduced due to lack of knowledge in political circles in London. And, since there were hardly any local outlets, the work wound down and finally closed.

Silicon Valley has followed the historical tradition of Manchester but with more tricks and waste.

35

London Again 2013

While at Stanford we had increasingly felt that we should be back in London. However, commuting from Menlo Park to London to look for a suitable home was not working well.

So, rom 2010, we made a temporary stay of about 3 years in Cold Spring, New York. We found that it was much easier to find a suitable place in London while mainly resident in the Hudson River Valley and flying from Boston. In the past we had in any case frequently commuted between the East Coast and London and the Continent. At least for us, jet lag is not a linear function of the number of hours of time zone difference.

During this time Ilse continued painting and exhibited of her work in the Royal Academy Summer Exhibitions.

Finally, we found a very attractive flat on the Kensington Palace grounds. It was also an exceptionally safe place to live through the COVID years since there was no public access, and our access included the private paddock extending to the Palace.

During this time I pursued interests in statistics, information, and reviewing some older work at AT&T and other interests. Some of this can be found at: archive.org or my entries on Researchgate. As seems well-known Researchgate seems to just do what it finds. We only accidentally provided our name!

35.1 Stanford and Menlo Park March 2022

To our great surprise a series of conditions arose which caused us to give up our home in Kensington Palace grounds and spend part of a

year in the same community where we had lived in Menlo Park. This was in order to re-experience what we had enjoyed in California and decide on our preferred location for the longer term. We quite quickly realized that the social, intellectual, political and physical climate made our choice clear. It is unlikely that we will ever return to California. In the former Silicon Valley most science and technology has dried up. The issues of poverty, increasingly dismal and ineffective education, expensive health care and social conflict have worsened. There is no immanent prospect of real improvement.

35.2 2023 Return to London

After a short stay in Knightsbridge and a search our new home we are well situated in Holland Park, close to where we lived for many years long ago. This is also where Carlos and Sheila Sancha lived. This gives us great memories and comfort.

So, unless major forces beyond our control cause another change, we are settled in London and look back on our great good fortune to have lived in such good times.

Of course, we hope that there may be times when we can return to Mad River and *ski it if we still can!*. Of course, Mad River's slogan is: **Ski it if you can!**

35.2.1 The Chelsea Arts Club

Shortly after our return our close friend Jean Baudrand suggested that Ilse should apply for membership in the Chelsea Arts Club. She went ahead with this, submitted works and met with the membership Committee and was accepted. Of course, with recommendation from Jean.

This has been a great benefit for us both, The Club is informal and the members are a pleasure to be with. And, it is a nice place for meals. Only one Club rule: NO mobile phones!!

And more: Friday night is Jazz night with an excellent band! This brings us back to the wonderful old times at Ronnie Scott's.

35.3 Surprise Request

As we were moving back to London David Zierler from Caltech contacted me about an interview. He is responsible for interviews with former Caltech students and somehow he found my name. After several sessions this ended up on the Caltech Archive site at: Zierler Interview. I had expected that this would be about Caltech during the time that I was a student but it also ended up as a chronicle of my experiences during that time. These were exciting times and an exceptional learning experience. Quite a bit of this does appear on the web at the Caltech Archive site above.

Only near the end of the interview sessions did I discover that I had been recommended by the current Caltech President Thomas Rosenbaum. And, he took enough interest to read through the interview. I cannot help feeling that this showed the kind of interest and capability that has made Caltech as exciting a place as when I was there.

I very much wish to acknowledge Zierler's many comments on this piece.

36

Close

We view our final time with sadness for those who will follow us. It seems inevitable that opportunities will continue to worsen both due to climate change and due the responses to the change. But it is also hard to imagine how and when the end may come.

As global warming progresses the habitable global land mass will decrease. This will surely cause major migrations which will also lead to conflict and, of course, many more heat induced deaths. It is important to read Attenborough's comprehensive analysis which is mentioned in Section 24.5.1. It is well worth reading with care.

However, there is no historical reference of such an event other than, paradoxically, the ice age. Another is possible, but not likely.

We enjoyed our time in relative civilization and tried our best to make useful contributions.

And we hold wonderful memories of these times.

37

Bibliography

[1] Allais, É. *La Méthode Française de Ski*. Éditions Flèche, 2, Rue du Helder, Paris, 1947. Available at archive.org: in French.

[2] Ampère, André-Marie. *THÉORIE DES PHÉNOMÈNES ÉLECTRO-DYNAMIQUES, UNIQUEMENT DÉDUITE DE L'EXPÉRIENCE*. MÉQUIGNON-MARVIS, LIBRAIRE-ÉDITEUR, RUE DU JARDINET, N° 13., Paris, 1826. Available at archive.org: in French or in English.

[3] Babbage, C. *Passages from the Life of a Philosopher*. Cambridge University Press, CLC, New York, 1864. Be sure to obtain this **digitally printed version 2011** from: Cambridge Core, or on the WEB at: Gutenberg.org.

[4] Bairavasundaram, L. N. & Arpaci-Dusseau, A. C. & Arpaci-Dusseau, R. H. & Goodson, G. R. & Schroeder, B. An Analysis of Data Corruption in the Storage Stack. *ACM Transactions on Storage (TOS)*, 4(3):8:2–8:28, Nov 2008. Available at: acm.org.

[5] Bairavasundaram, L. N. & Arpaci-Dusseau, A. C. & Arpaci-Dusseau, R. H. & Goodson, G. R. & Schroeder, B. Corruption in the Storage Stack: a closer look. *The Usenix Magazine*, 33(3):6–14, Jun 2008. Available at: usenix.org.

[6] Beth, R. A. Mechanical Detection and Measurement of the Angular Momentum of Light. *Phys. Rev.*, 50:115–125, 1936.

[7] Bickmore, D. *Automatic Cartography and Planning*. Architectural Press, London, UK, 1971. Experimental Cartography Unit of the Royal College of Art.

[8] Bingham, C. & Godfrey, M. D. & Tukey, J. W. Modern Methods of Power Spectrum Estimation. *IEEE Transactions on Audio and Electroacoustics*, AU-15(2):56–66, 1967. Available at: ResearchGate.

[9] Birkhoff, G. & von Neumann, J. The Logic of Quantum Mechanics. *Ann. Math.*, 37(4):823–843, Oct. 1936.

[10] Blackman, R. B. & Tukey, J. W. *The Measurement of Power Spectra*. Dover, New York, 1959.

[11] Breedlove, R. L. & Godfrey, M. D. *An Incremental Cost Model of Message Toll Telephone Services*. American Telephone and Telegraph Company, 195 Broadway, New York, NY, 1975. Available at: archive.org.

[12] Callen, H. B. *Thermodynamics and an Introduction to Thermostatistics, 2nd edn.* John Wiley & Sons, New Delhi, 1985. Note: Only this edition contains the Postlude: Symmetry and the Conceptual Foundations of Thermostatistics.

[13] Carson, R. *Silent Spring*. Houghton Mifflin, 125 High Street, Boston, MA 02110, USA, 1962.

[14] Coll, S. *The Deal of the Century, The Breakup of AT&T*. Collier Macmillan Canada, Inc., Collier Macmillan Canada, 1986.

[15] Cramer, J. G. The Transactional Interpretation of Quantum Mechanics. *Rev. Mod. Phys.*, 58, No. 3:647–687, Jul 1986.

[16] Deitel, H. M. & Kogan, M. S. *The Design of OS/2*. Addison-Wesley Publishing Company, Reading, Massachusetts, 1992.

[17] Einstein, A. Zum gegenwärtigen Stand des Strahlungsproblems. *Physik. Z.*, 10(6):185–193, 1909. Available here in German and here in English.

[18] Feynman, R. P. & Leighton, R. B. & Sands, M. *The Feynman Lectures on Physics*. Addison Wesley, Reading, Mass., 1963. Updated edition available at: www.feynmanlectures.caltech.edu.

[19] Fowler, B. & Godfrey, M. D. & Mims, S. Reset Noise Reduction in Capacitive Sensors. *IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS—I: REGULAR PAPERS*, 53(8):1658–1669, 2006.

[20] Gabor, D. Communication Theory and Physics. *Transactions of the IRE Professional Group on Information Theory (New title from 1950:, IEEE Trans. on Inf. Th.)*, 1(1):48–59, 1953. Available at: Archive.org.

[21] Gladstone, J. H. *Michael Faraday*. CLC, Cambridge University Press, Cambridge, UK, 1872.

[22] Grove, A. S. *Physics and Technology of Semiconductor Devices*. John Wiley & Sons, New York, 1967.

[23] Hoeneisen, B. & Mead, C. A. Fundamental limitations in Microelectronics-I. MOS Technology. *Solid-State Electronics*, 15:819–829, 1972.

[24] Holt, R. P. F., editor. *The Selected Letters of John Kenneth Galbraith*. Cambridge University Press, New York, USA, 2017.

[25] Huygens, C. *Traité de la Lumière*. Pierre van der Aa, Leiden, 1678, 1690. English trans: S. P. Thompson, U. Chicago Press, 1912 at: www.gutenberg.org or at: www.archive.org, or in French including Huygens' Discours on the Theory of Gravity at: www.archive.org.

[26] Infield, Glenn, B. *The Poltava Affair - A Russian Warning : An American Tragedy*. Macmillan Publishing Company Inc., 1973.

[27] Jaynes, E. T. Probability in Quantum Theory. In Zurek, W. H., editor, *Proceedings: Complexity, Entropy and Physics of Information*. Addison-Wesley, Reading, MA, 1990.

[28] Jaynes, E. T. *Probability Theory: The Logic of Science*. Cambridge University Press, Cambridge, UK, 2003.

[29] Koestler, A., Koestler, C., Harris, H. *Stranger on the Square*. Abacus Books, 1985.

[30] Maxwell, J. C. *A Trestise on Electricity and Magnetism*, volume 2. Dover, New York, 1954.

[31] McGlynn, Robert. *10 Trial Sreet*. The Deerfield Press, 1979.

[32] Mead, C. A. Scaling of MOS Technology to Submicrometer Feature Sizes. *Journal of VLSI Signal Processing*, 8:9–25, 1994. Available at: Caltech.

[33] Mead, C. A. *Collective Electrodynamics, Quantum Foundations of Electromagnetism*. MIT Press, MA, 2000, ISBN: 0-262-13378-4.

[34] Moore, G. E. Cramming more components into integrated circuits. *Electronics Magazine*, 38(8), April 19 1965.

[35] Morgenstern, O. *On the Accuracy of Economic Observations*. PUP, Princeton, 2nd. edn., 1963. Available for loan at: Internet Archive.

[36] Needham, J. *Science in Traditional China*. Harvard University Press, Cambridge, MA, USA, 1981.

[37] Nyblén, G. *The Problem of Summation in Economic Science*. Gleerup, Lund, Sweden, 1951. Available at: archive.org.

[38] Pauling, Linus. *General Chemistry*. W. H. Freeman And Company, 1958.

[39] Poynting, J. H. The Wave Motion of a Revolving Shaft, and a Suggestion as to the Angular Momentum in a Beam of Circularly Polarized Light. *Proc. R. Soc.*, Series A(82):560–567, 1909. Available at: archive.org.

[40] Rédei, M. The Birth of Quantum Logic. *Hist. and Phil. Logic*, 28: 107–122, 2007.

[41] Resnikoff, H. L. & Wells, R. O. *Wavelet Analysis: the scalable structure of information*. Springer Science+Business Media, New York, 1998.

[42] Sancha, S. *Knight after Knight*. Collins, 1974.

[43] Sancha, S. *Lincoln Castle: The Medieval Story*. The King's England Press, 1985.

[44] Schrödinger, E. *Science and Humanism*. Cambridge University Press, Cambridge, 1951.

[45] Shannon, C. E. A Mathematical Theory of Communication. *Bell Syst Tech J*, 27(3, 4):379–423, 623–656, 1948. Available at: math.harvard.edu.

[46] Szilard, L. Über die Entropieverminderung in einem thermodynamischen System bei Eingriffen intelligenter Wesen. *Z. Phys.*, 53 (11-12):840–856, 1929. Available at: library.ucsd.edu.

[47] Szilard, L. On the decrease of entropy in a thermodynamic system by the intervention of intelligent beings. *Behav. Sci., Rapoport and Knoller trans: Szilard, 1929*, 9(i. 4):301–310, 1964.

[48] Tufte, E. *Beautiful Evidence*. Graphics Press, LLC, Cheshire, Connecticut, 06410, USA, 2006. Available at: (book 4) www.eduardtufte.com.

[49] von Neumann, J. Über ein Ökonomisches Gleichungssystem und eine Verallgemeinerung des Brouwerschem Fixpunktsatzes. *Ergebnisse eines mathematisches Kolloquiums*, 8:73–83, 1937. English trans: A Model of General Economic Equilibrium, *The Review of Economic Studies*, v. 46, pp.1–9, 1945.

[50] von Neumann, J. *Lectures on Probabilistic Logics and the Synthesis of Reliable Organisms from Unreliable Components. Notes prepared by R. S. Pierce*. California Institute of Technology, 1952. Original

Notes available at: archive.org or edited typescripts in: Automata Studies, ed. C. Shannon, Princeton University Press, 1956, or ed. A. H. Taub, John Von Newmann, Collected Works, Vol. 5, pp. 329–378, 1963.

[51] von Neumann, J. & Morgenstern, O. *Theory of Games and Economic Behavior*. PUP, Princeton NJ, 3 edition, 1953.

[52] Williams, L. Pearce. *Michael Faraday: A biography*. Basic Books, New York, 1965.

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